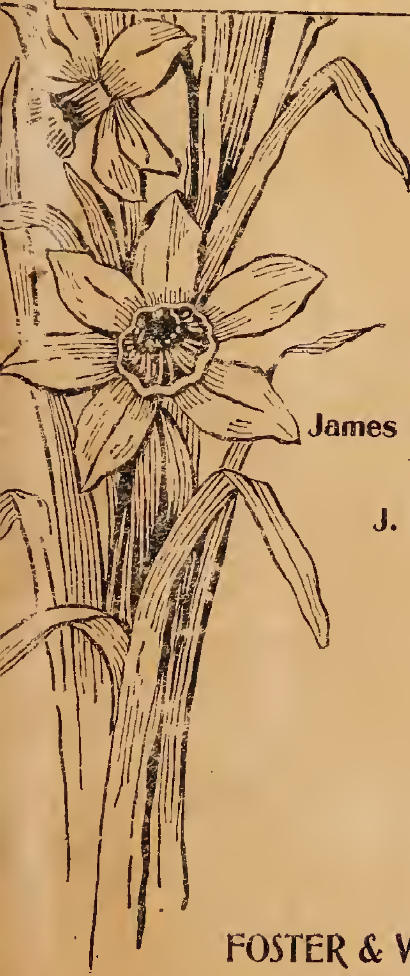
THE ELEMENTS OF THE GEOLOGY OF TENNESSEE



By

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THE ELEMENTS

OF

THE GEOLOGY OF TENNESSEE.

PREPARED FOR

THE USE OF THE SCHOOLS OF TENNESSEE,

AND FOR ALL PERSONS SEEKING A KNOWLEDGE OF THE RESOURCES OF THE STATE.

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PREFACE.

THIS work on the elementary geology of Tennessee was prepared for the use of schools as well as for the use of all persons interested in the study of the resources of the State. The predominant idea in its preparation was to give to the young people of the State some knowledge of the great commonwealth in which they live, and further to enable them to impart to others some idea of its vast and varied resources, its beautiful landscapes, its grand rivers, and its lovely climate. Such knowledge will be of the utmost value to all citizens, whether young or old, and will not only be useful from an economical point of view, but it will be a source of perpetual pleasure throughout their lives. Students in the lower grades, and those in the common schools who do not intend to take a high school or collegiate course, should study Parts I. and IV. only. Advanced students may study the whole book, with profit.

The authors desire to express their grateful acknowledgments to Maj. H. C. Bate, the local forecast official and section director of the weather bureau at Nashville, for contributing the larger portion of the chapter on the "Climate of Tennessee," which is full of interesting and useful data.

Having spent a large portion of their lives in the study of the geology and resources of Tennessee, the authors hope that the work herewith presented may meet the approval of the teachers of the State.

JAMES M. SAFFORD,
J. B. KILLEBREW.

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GEOLOGY OF TENNESSEE.

INTRODUCTION.

The Study of Geology: Its Object and the Parts of the Work. Where to Begin.

1. The study of the crust or the outer part of the earth, which is the object of geology, is one of great importance, and may well engage the attention of every class. In this way we learn of the soils, which yield us food; the coal, which warms us and makes the steam to drive our engines; the ores, which supply our metals; the clays for pottery; the materials for building; and the stones and gems we use for adornment.

2. Thus we see how intimately geological studies connect themselves with the affairs and details of common life. We may add further that the study of geology forms habits of observation and investigation; it trains us to see and search, by far the most important parts of our education and which are too often neglected. The considerations mentioned give geology a high place among the studies pursued in schools.

The subject will be divided into four parts. These are indicated below in the order in which they will be treated.

3. I. The State in General.—At the beginning of our

inquiry we ought to take a cursory view of the State as a whole. We must know its boundaries, outlines, and area. We must pass over its surface, noting the portions which rise in mountains and highlands and those which sink in basins and valleys, or, in other words, we must see how its surface is naturally divided. Nor will it be amiss to inquire into the elevation of the State above the sea, its river system, climate, and other features. These are general characteristics, and a knowledge of them places the field fairly before us. After this general view, we can study the special features of the surface divisions, their extent and form, their height or depth, as the case may be, the river system or drainage, whether presenting rich or poor lands, and whether populous or not. This will be, in the main, preliminary to what is to follow; but the information thus gained will be full of interest and highly desirable in itself.

4. **II. The Rock-beds or Strata.**—Our second step will be to investigate the rocks, which, though sometimes outcropping or showing themselves in glades, ledges, and cliffs, lie mainly beneath the surface. To prepare ourselves for this we must first become familiar with the different kinds of minerals or mineral substances which enter into the composition of rocks, and then with the various kinds of rocks themselves, all of which can be done in a room, with hand specimens of proper minerals or rocks on a table before us. This accomplished, we shall be ready to study in the open air the rock-beds or strata which make up the hills and

mountains and underlie the valleys. We shall see that they lie in a horizontal position or are inclined; that they are thick or thin; of limestone, sandstone, shale, slate, or other rock; that they sometimes contain the remains of animals, as shells and corals, often in great profusion, as well as the remains of plants.

5. **III. The Geological Formations.**—The next stage of our study will be to make out the great formations of the State.

And first what do we mean by *formation?* How does it differ from a rock-bed or *stratum?* The word *stratum* is a Latin word, and means that which is *spread out;* the plural is *strata.* A stratum is a bed of the same kind of rock, as a stratum of limestone or a stratum of sandstone. It includes all of any one kind that lies together. It may be a few or many feet thick and may consist of many *layers,* provided they are all of the same rock-material. A *formation* is often a series or a pile of many strata. It may include beds of limestone, sandstone, and of other rocks. It is a series, the strata of which have been formed or deposited successively in what geologists call one *age* or one *period* of time. The Carboniferous formation is an example. This embraces many beds of sandstone, limestone, shale, and coal, alternating more or less with each other. The series makes a formation because the strata were deposited during the age when the coal beds were formed—an age of long duration —when the lands in many regions were covered with a forest growth remarkable for its luxuriance, and for the strange forms of its shrubs and trees.

The study of the formations found in Tennessee will be in some respects the most important part of our work. They constitute, as we shall see, the foundation of geological science. We have to learn as nearly as

we can the thickness of each, the kind of strata making it up, the areas within which it outcrops or comes to the surface, the fossil remains imbedded in it, the ores, minerals, useful rocks, and soils it contains or may yield.

6. **IV. Economic Geology. The Minerals, Ores, Useful Rocks, and Soils.**—With the formations determined and disposed of, as mentioned in the last section, our work will be well advanced. It remains to go over and glean the field, bringing together in a body, for further notice and easy reference, all that may have economic or practical value. In this class we include coal, iron ores, and other ores and minerals, marble, cement-limestone, phosphate rock, and useful rocks generally, and lastly soils. In connection with these, important ore banks and mines may be described.

In commencing the study of geology let the student, in connection with his text-book, make practical work of it. *Begin right at home.* Let him observe carefully the different beds of rock that he has been playing or hunting over; see whether they are of limestone, sandstone, shale, or other rock; observe the color, hardness, structure, how thick the layers are, the order in which they occur, whether they contain shells or minerals; if containing shells, let him study these until he knows their forms and can distinguish one from another. If living in East Tennessee, let him further notice that the strata of rocks are often inclined. By close observation he may be able to see that they sometimes occur in folds, as if they had once

been great flexible sheets and had been squeezed together by some powerful force.

7. By work of this sort, which any apt and zealous pupil of fifteen can carry out, the rocks of one's neighborhood, seen in the fields and hills and outcropping in the branches, will become known, and so well known as, like the faces of familiar friends, to be easily recognized when met with in other and distant places. Many a distinguished geologist, with but little assistance from books or teachers, commenced his career just in this way.

PART I.

THE STATE IN GENERAL, TOPOGRAPHY, DIVISIONS, AND CLIMATE.

CHAPTER I.

8. Form, Length, Width, Area, and River System.—When seen upon the map, the State of Tennessee has nearly the form of a long rhomboid. While its average width is only 109 miles, its length is as much as 385, which makes the State three and a half times as long as wide. A straight railroad track connecting its two sharp diagonal corners, the one near Memphis, and the other to the northeast on the Virginia line, would be nearly 500 miles long. The entire area of the State is about 42,050 square miles, of which 300 square miles are covered by water.

Fig. 1.

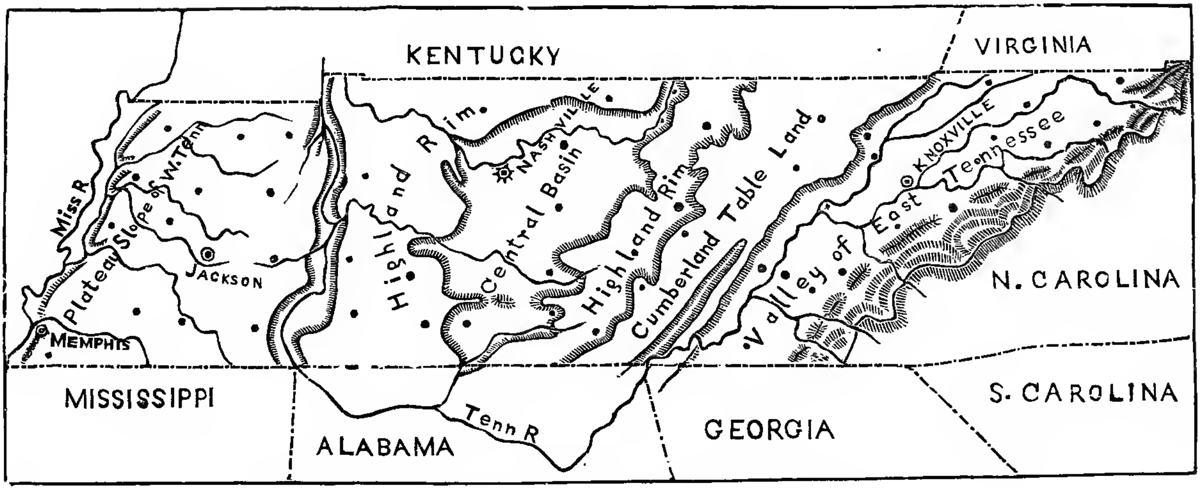
A Rhomboid.

9. On page 8 is a *surface* or *topographical* map of the State. It shows the form and boundaries of Tennessee, and gives the names of all the States which touch it excepting Missouri and Arkansas. Eight States touch our borders. With the exception of Missouri, no other State in the Union is touched by so many.

10. East and West Boundaries, the Westerly Inclination and Drainage.—Tennessee lies lengthwise, directly east and west, between the crest of one of the highest ranges of the Appalachian Mountains and the Missis-

sippi river. Its eastern boundary, or, as we may say, its North Carolina boundary, has an average elevation of 5,000 feet above the sea, while the lowlands bordering the Mississippi rise to the height of only about 300. This indicates a great tilting or inclination of the surface to the west. The inclination exists, but in a far less degree than the difference in the elevation of the two boundaries would denote. The eastern mountains form a very massive and raised border, but they do not reach very far into the State. At their foot lies the great *Valley of East Tennessee* (see map), the average elevation of which is not much above that of the middle portion of the State. This elevation may be placed at 1,000 feet above the sea. From this valley the general surface of the State (excluding the *Cumberland Table-land*, which, as we shall understand hereafter, is a great barrier in the way of the rivers) descends very gradually to the west. The average direction of drainage, or the average direction in which the waters flow, conforms to this. It may be observed, and the map shows it well, that the rivers flow, to a remarkable degree, in two directions, one to the southwest and the other to the northwest. The tendency or mean direction of these, however, is westerly.

11. River System.—The State is rich in water courses. Hundreds of streams water the land, supply motive power, and enliven the valleys. The Mississippi, the Tennessee, and the Cumberland, with their principal tributaries, are the largest rivers of the State. The Tennessee and the Cumberland pour their contents first



SURFACE MAP OF TENNESSEE.

Scale, about 75 miles to the inch.

NOTE.—The following natural divisions are not named on the map: the Unaka range of mountains bordering the North Carolina line, the Western Valley of the Tennessee river (the narrow valley through which the Tennessee river runs into Kentucky), and the Mississippi Bottoms, a low and narrow area bordering the Mississippi river. The names *Plateau Slope of West Tennessee* ought to run through Jackson to be in the center of the division which it indicates.

into the Ohio, and then into the Mississippi, so that all the water which drains off from the surface of Tennessee (with the exception of that from a small spot near a corner of the State, next to the Georgia line, and hardly worth the mention) finds its way through the Mississippi to the Gulf. The rivers named are navigable, and are means of transportation, much to the advantage of the State's material interests. The Tennessee river is peculiarly our own. Its principal head waters are in Virginia and North Carolina. Starting in Virginia, its waters cross Tennessee twice, receiving many tributaries, and draining two-thirds of the State. The Cumberland has no great volume of water, but is remarkable for being navigable, canal-like, for 518 miles, 315 of which are in Tennessee, and the remainder in Kentucky. The Tennessee river furnishes to the State 320 miles of navigable water, and the Mississippi river nearly 200 miles. Altogether there are approximately 1,200 miles in length of navigable streams in Tennessee.

12. The eastern portion of the State has been well called the "Switzerland of America" by reason of its high mountains and deep valleys. If the student will examine any good map of the United States and Canada, he will see a long, narrow, mountainous area stretching in a southwesterly direction all the way from Vermont to Middle Alabama, traversing all the intermediate States. This range is remarkable for its long, straight, and parallel mountains with intervening valleys. It is called the Appalachian Belt, the length of which is 1,200 miles and its width from 50 to 100 miles.

13. Many of the mountains and valleys of this belt have special names. The Alleghany range of Pennsylvania and Virginia becomes the Cumberland Table-land in Tennessee and the Sand Mountain in Alabama. The Blue Ridge of Pennsylvania, Virginia, and North Carolina takes the name of the Unaka or Smoky range. The Holston, the Clinch, and Lookout are a few among many of these mountains in Tennessee. The long, straight valleys lying between the parallel ridges and overlooked by them, but open to the northeast and southwest, are often rich, populous and beautiful—centers in which industry, intelligence, and a diversified system of agriculture prevail.

14. The Great Valley of East Tennessee, in which Knoxville is situated, is made up of many minor ridges and valleys. It lies between the eastern border mountains and the Cumberland Table-land, and has an average width of 45 miles.

It will be described more in detail in another chapter.

CHAPTER II.

The Natural and Civil Divisions of the State.

15. Natural Divisions.—There are eight natural divisions in Tennessee, with the following names:

I. The Unaka Range.
II. The Valley of East Tennessee.
III. The Cumberland Table-land.
IV. The Highland Rim.

V. The Central Basin.
VI. The Western Valley of the Tennessee River.
VII. The Plateau of West Tennessee.
VIII. The Mississippi Bottoms.

16. There are three civil or political divisions constructed out of the eight natural divisions as follows:

I. East Tennessee.—Comprising all the territory from the North Carolina boundary to about a line passing though the center of the Cumberand Table-land, embracing the first and second natural divisions, and about half of the third; land area, 13,112 square miles.

II. Middle Tennessee.—Extending from the dividing line on the Cumberland Table-land to the Tennessee river, and comprising the whole of the fourth and fifth natural divisions and about half of the third and sixth; land area, 18,126 square miles.

III. West Tennessee.—Extending from the Tennessee river to the Mississippi and including the whole of the seventh and eighth natural divisions and half of the sixth; land area, 10,512 square miles.

To these land areas must be added 300 square miles of water area, most of which is taken up by the lakes and rivers of West Tennessee. These three civil divisions are subdivided into 96 counties.

17. East Tennessee has 34 counties, as follows:

County.	County Seat.	County.	County Seat.
Anderson	Clinton.	Grainger	Rutledge.
Bledsoe	Pikeville.	Greene	Greeneville.
Blount	Maryville.	Hamblen	Morristown.
Bradley	Cleveland.	Hamilton	Chattanooga.
Campbell	Jacksboro.	Hancock	Sneedville.
Carter	Elizabethton.	Hawkins	Rogersville.
Claiborne	Tazewell.	James	Ooltewah.
Cocke	Newport.	Jefferson	Dandridge.

County.	County Seat.	County.	County Seat.
Johnson	Mountain City.	Rhea	Dayton.
Knox	Knoxville.	Roane	Kingston.
Loudon	Loudon.	Scott	Huntsville.
McMinn	Athens.	Sevier	Sevierville.
Marion	Jasper.	Sequatchee	Dunlap.
Meigs	Decatur.	Sullivan	Blountville.
Monroe	Madisonville.	Unicoi	Erwin.
Morgan	Wartburg.	Union	Maynardville.
Polk	Benton.	Washington	Jonesboro.

18. Middle Tennessee has 41—viz.:

Bedford	Shelbyville.	Marshall	Lewisburg.
Cannon	Woodbury.	Maury	Columbia.
Cheatham	Ashland City.	Montgomery	Clarksville.
Clay	Celina.	Moore	Lynchburg.
Coffee	Manchester.	Overton	Livingston.
Cumberland	Crossville.	Perry	Linden.
Davidson	Nashville.	Pickett	Byrdstown.
Dickson	Charlotte.	Putnam	Cookeville.
De Kalb	Smithville.	Smith	Carthage.
Fentress	Jamestown.	Robertson	Springfield.
Franklin	Winchester.	Rutherford	Murfreesboro.
Giles	Pulaski.	Stewart	Dover.
Grundy	Altamont.	Sumner	Gallatin.
Hickman	Centerville.	Trousdale	Hartsville.
Houston	Erin.	Van Buren	Spencer.
Humphreys	Waverly.	Warren	McMinnville.
Jackson	Gainesboro.	Wayne	Waynesboro.
Lawrence	Lawrenceburg.	White	Sparta.
Lewis	Hohenwald.	Williamson	Franklin.
Lincoln	Fayetteville.	Wilson	Lebanon.
Macon	La Fayette.		

19. West Tennessee has 21—viz.:

Benton	Camden.	Dyer	Dyersburg.
Decatur	Decaturville.	Carroll	Huntingdon.

County.	County Seat.	County.	County Seat.
Chester	Henderson.	Lake	Tiptonville.
Crockett	Alamo.	Lauderdale	Ripley.
Fayette	Somerville.	Madison	Jackson.
Gibson	Trenton.	McNairy	Selmer.
Hardeman	Bolivar.	Obion	Union City.
Hardin	Savannah.	Shelby	Memphis.
Haywood	Brownsville.	Tipton	Covington.
Henderson	Lexington.	Weakley	Dresden.
Henry	Paris.		

CHAPTER III.

THE MOUNTAINOUS DIVISIONS OF THE STATE, COMPRISING THE UNAKA RANGE, THE VALLEY OF EAST TENNESSEE, AND THE CUMBERLAND TABLE-LAND.

I. THE UNAKA RANGE.

20. Its Position, Extent, and Elevation.—This is the greatest of all the Appalachian ranges, and extends for the distance of 200 miles along the eastern border of Tennessee. That portion lying between Virginia and Georgia presents the greatest mountain mass east of the Mississippi river. The average elevation of the range is 5,000 feet, but many of its peaks reach a height of more than 6,000 feet above the sea. The peaks are often concealed in the clouds for days together.

21. Its highest crest is the line separating Tennessee from North Carolina. The range is about equally divided between the two States. The portion within Tennessee (and to this we confine our attention) occupies a strip which, in width, will average thirteen miles, but varies from two to twenty, and has an area of 2,000 square miles. The area thus occupied is indicated on the map by the fine lines representing mountains, and lies between North Carolina and the Valley of East Tennessee.

22. **The Unaka Range—A Belt of Parallel Ridges. The Main Axis.**—The Unaka Range is not a single ridge, but is, in Tennessee, a belt of parallel ridges which vary at different points, counted across the range, from two to four in number. The easterly one, on whose crest is the North Carolina line, is the main axis, the others are lower and subordinate. The main axis (by axis is meant the main ridge, to which the others are subordinate) has many names applied to it at different points along its course, Iron Mountain, Roan, Big Bald, Great Smoky, and Frog, being some of them.

23. **The Chilhowee Subordinate Range.**—The most westerly or northwesterly mountains of the range lie detached from the spurs of the main axis, and just within the Valley of East Tennessee. They are isolated mountains, but are arranged lengthwise, as may be seen on the map, along a curving line. These mountains are the first approached from the valley, and are for that reason quite conspicuous, though much lower than the towering, cloud-capped crests behind them. This line

of subordinate mountains may be called the Chilhowee range. Among its mountains are the Holston, Buffalo, Meadow Creek, English's, Chilhowee, and Star's mountains.

24. Included Valleys and Coves.—Interlocked with the great ridges and spurs of the Unaka Range, or entirely surrounded by them, are many beautiful valleys and coves. The cultivated part of one county, Johnson, in the northeastern corner of the State, is a mountain-hemmed cove, with no way of getting in or out except by scaling mountains or passing through certain narrow, dark, and rocky gaps made by the streams. Another small cove is Shady. Other interesting coves are Wear's, in Sevier County, and Tuckaleechee and Cade's coves, in Blount. But these included valleys and coves, many more of which might be mentioned, are properly parts or outliers of the great valley next to be described.

25. Cut Transversely by Rivers.—Notwithstanding the massive character of the Unaka Range, it is cut into many portions by the rivers which flow out of North Carolina. This is a remarkable fact. The rivers take their rise on the western slope of the Blue Ridge (an Appalachian ridge lying to the east in North Carolina and not so high or so massive as the Unaka), flow in a north-westerly direction, and intersect the Unaka Range in deep, grand cuts, often with cliffs on both sides rising hundreds of feet in height, the waters dashing over the rocks in long and roaring rapids. A few years ago these cuts were impassable for travellers; but now many of them supply good roads, and through several of

them railroad lines have been built. There are seven rivers thus cutting the range — all tributaries of the Tennessee.

26. The Balds. — Generally the Unaka ridges are clothed with forests. The high summits, however, are often destitute of trees, owing to the cold of this elevation. Such places are called the "Balds." They are treeless domes capping the great mountains, yet they are covered with grasses, ferns, and small shrubs, some of which belong to a far more northern climate than is found in the valleys below. In the summer season the Balds are favorite resorts for pleasure seekers and those who would escape the heat of the valleys. The cool air and the grasses attract herdsmen with their cattle, and in July and August the more desirable of the summits are often alive with stock of all kinds. Heavy rain storms, accompanied by thunder and lightning, may often be seen in the valley below, while the top of the mountain is bathed in sunshine. Sometimes the clouds envelop the mountain, and one may indulge in the rare privilege of being wrapped in the mist of a thunder cloud, with the lightning playing familiarly about him.

27. Views.—The views from the Balds are magnificent. To the east, in North Carolina, is a vast billowy sea of mountains; to the west, in Tennessee, far below, at the foot of the Unakas, lies the Valley of East Tennessee, its surface spread out like a checkered carpet, its inequalities, excepting a few prominent ridges to the north, being almost lost—the surface sinking down to a plain,

dotted over with cultivated spots. In the extreme distance the Cumberland Table-land is seen rising up dimly beyond the great valley and bounding the view. Many of our minerals and ores are found in this range.

II. The Valley of East Tennessee, or the Great Valley.

28. Boundaries and Extent. — Descending from the mountains, we enter the Valley of East Tennessee, a most beautiful and desirable portion of the State, embracing nearly all the wealth and population of the civil division we call East Tennessee. Its position and outlines are well shown upon the map. It lies between the Unaka Range on the southeast and the Cumberland Table-land on the northwest, the average distance between these divisions being about 45 miles. Though thus bounded by mountain walls on both sides, it is open to the northeast into Virginia, and to the southwest into Georgia. The city of Knoxville is near its center, and Chattanaoga is at its southwestern corner. Its area, including its outlying valleys and coves, is about 9,200 square miles, which is more than one-fifth of the area of the State.

29. Elevation above the Sea.—The average elevation of this valley has been placed at 1,000 feet above the sea. Its elevation on the Virginia line will average about 1,400 feet, at Knoxville about 900, and on the Georgia line 800. Thus it will be seen that the greatest fall occurs before reaching Knoxville. Below this point it

is much less. In the northern part of the valley the rivers run rapidly, have more shoals, and are less suited for navigation than they are below Knoxville. Though not so well suited for navigation, a compensation is found in their fitness for water power.

30. A Succession of Minor Valleys and Ridges.—The Valley of East Tennessee has been so often referred to that the attentive student must be already familiar with its leading characteristics. Seen from the mountains, its surface is almost a plain; but in crossing it we find it to be a succession of minor valleys and ridges, which run to the northeast and southwest, and, like furrows, in parallel lines. In this it conforms to the characteristic features of the Appalachian Belt, of which it is a part. It is well called a fluted area.

31. The Ridges of the Valley.—The ridges are very numerous and differ in size, height, breadth, sharpness of outline, and in character of vegetation; while at the same time each one is remarkable for its direct course and uniformity in size and appearance from one end to the other, a distance often of a hundred miles or more. The ridges differ from each other on account of differences in their geological character.

32. The ridges may be grouped into three classes—viz., mountain ridges, broad ridges with level or rounded tops, and narrow and sharp-crested ridges. White Oak mountain, in the southern part of the Valley of East Tennessee, Clinch mountain, about midway between the Unaka mountains and the Cumberland Table-land, Newman's ridge and Powell's mountain, in the northern part of the valley, are examples of the mountain ridges. The broad ridges have cultivated fields on them and sometimes

towns. Knoxville is built on one and a part of Athens on another. Black Oak, Copper, and Chestnut ridges, all large ridges crossed in going northwest from Knoxville, come under this head. The narrow ridges resemble the roof of a house. The top is often serrated or notched. When these notches are deep the ridge forms a line of knobs, as the line of red hills which, starting near Strawberry Plains, passes in sight of Knoxville and Athens and terminates near the Georgia line. These look like mammoth potato hills, and the line is nearly 100 miles long.

33. The Minor Valleys and Coves.—They are very numerous, like the ridges. All of them have names, which it is not necessary to enumerate. The valleys have great length, two of them, though not averaging more than a mile in width, run continuously through the State, from Virginia to Georgia, a distance of more than 150 miles. In general they vary in width from a few hundred yards to several miles. Most of them are fertile and beautiful. Some of the narrow ones are not inviting, being cold and unproductive.

34. Nearly every portion of a valley has its creek, flowing either to the northeast or southwest, in conformity with the direction of the ridges. If the creek escapes from one valley into another, it does so through a narrow gap in a ridge, and then only to flow off in a direction parallel to its first course.

35. Sequatchee* (or Sequachee) Valley is a great, deep trough, cut lengthwise out of the table-land, dividing it into two parallel but unequal arms, the more easterly being *Walden's*

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*NOTE.—Usually spelled with the termination *ie*. In this work it is restored to its original termination of *ee*.

ridge. This valley has its head about midway between the northern and the southern boundaries of the State, and extends to the Alabama line, a distance of sixty miles. It is from three to five miles wide, and is inclosed by walls of stone nearly 1,000 feet in height. It is an admirable place to study the geological formations. There are eight or ten distinct formations exposed in the valley and on its sides.

36. The rocks of all valleys and coves that have agricultural importance are limestone or soft shales intermixed with limestone.

III. The Cumberland Table-land.

37. Defined; Elevation, Area, Outlines, Walden's Ridge. Next in order comes the Cumberland Table-land, the third natural division of the State. This is the region of coal, a high plateau or table, capped with sandstone. It rises 1,000 feet above the Valley of East Tennessee and 2,000 feet above the sea. It embraces 5,100 square miles, which is one-eighth of the State. The form, relative size, and oblique direction of the table-land are seen upon the map on page 8. Its eastern edge is a nearly direct or gracefully curving line, while its western edge is notched and scalloped by deep coves and valleys, which are separated by finger-like spurs pointing to the west. At almost all points, on both sides the surface suddenly breaks off in sandstone cliffs from 20 to 200 feet in height, giving everywhere a sharp and very prominent margin or brow to the division.

38. Surface and Soil.—The surface of the table-land is often flat for miles. Then again it is rolling and diver-

sified with hills and shallow valleys. In the northeastern part of the division there are high ridges, containing many beds of coal, which may be regarded as mountains on the table-land.

39. The soil of the division is sandy, thin, and porous, but is suited for the growing of fruits and vegetables.

The Cumberland Table-land once formed an obstacle to free intercourse between Middle and West Tennessee, but it is now scaled by railroads at several points.

CHAPTER IV.

THE NON-MOUNTAINOUS NATURAL DIVISIONS, EMBRACING THE HIGHLAND RIM, THE CENTRAL BASIN, THE WESTERN VALLEY, THE PLATEAU-SLOPE OF WEST TENNESSEE, AND THE MISSISSIPPI BOTTOMS.

IV. THE HIGHLAND RIM, OR RIM-LANDS, OR TERRACE-LANDS.

40. Extent and Rim Character.—This is the most varied in its general features of any of the natural divisions. It has broad plains, deep valleys, productive farming areas, rich deposits of minerals, including iron ores and phosphates, grand waterfalls, and good navigable streams. This Highland Rim extends from the western base of the Cumberland Table-land to the Tennessee river, a distance of 120 miles. It encircles, as a flat country does

a lake, the great basin next to be described. It is the fourth and largest natural division in the State, and rises from 550 to 1,000 feet above the sea. It is a rim around a basin.

In form it approaches a square. The portion west of the basin is twice as wide as that on the eastern side. The entire area is 9,300 square miles.

41. **Surface, Soils, Iron Ore, and Phosphates.**—The surface of the rim, though greatly diversified in places, is generally flat. Many parts, however, are furrowed by streams, giving a pleasing variety of hill and dale. Some sections are especially adapted to the growth of tobacco, corn, wheat, and peanuts. These are thickly settled and in good cultivation. In other sections the lands are thin and sparsely inhabited.

On the western side of this division are iron ore banks, and immense phosphate deposits, which will be noticed under the head of Economic Geology.

V. The Central Basin.

42. **Name, Importance, Form, Rivers, and Area.**—The Central Basin is surrounded by the Highland Rim last described. It is the fifth division of the State and the most important, so far as fertility of soil, density of population, and political influence are concerned.

43. The Central Basin is oval in general form, lies lengthwise across, but within, the State, and forms the central area. Nashville, the capital, is in it. It has three rivers, the Cumberland, the Duck, and the Elk, and these escape from the basin in narrow and deep valleys, or out-

lets, cut through the western and southern portions of the rim.

The greatest length of the basin is 120 miles, its greatest width 55, and its area 5,450 square miles—more than an eighth of the State. Its depth below the rim will average 350 feet.

44. The Bed of a Drained Lake.—For the better understanding of this singular and important division, we may suppose it to be the bed of a drained lake, the edge or rim, which runs all around, having been the former shore. Indeed, if now the narrow outlets of the three rivers mentioned were dammed up level with the rim, the entire basin would fill with water and become a lake. At Nashville the lake would be 400 feet deep, and one might sail over the city and never recognize its site. The summits of the highest hills of the basin would stand out above the water as low scattered islands.

45. The most valuable mineral found in the basin is the phosphate of lime, or, as commonly called, phosphate rock. This exists in largest quantity in Maury, Williamson, Sumner, Giles, and Davidson. Other counties have valuable deposits of it.

VI. The Western Valley of the Tennessee River, or the Western Valley.

46. Character, Area, and Elevation.—This is comparatively a narrow valley, extending almost directly north and south through the State. The Tennessee river runs in a northerly direction through it, but the division is

broken, and by no means such a valley as we should expect to find upon so noble a river. The soil is fertile, and many good farming regions are met with, but marshy areas, covered with cypress swamps, often occur. The average width of the valley is 10 or 11 miles. It has an area of 1,200 square miles, and an elevation of 350 feet above the sea. Its iron ores, marbles, cement limestones, and the "bald places" in McNairy and contiguous counties are subjects of interest and will be more fully treated in other places.

VII. The Plateau, or Plateau-slope of West Tennessee.

47. Importance; Contrasted with the Other Divisions.—This division includes all the uplands in West Tennessee. It ranks third in size and second in population.

It is an area, not of limestone, sandstones, and other hard rocks, like the divisions we have described, but of clays, loams, and sands. For this reason it is like a new land to a traveller from Middle Tennessee. He misses the rocks in the bluffs of the streams, in the railroad cuts, and on the hills and ridges. The mellow soils are different, the rivers are sluggish, not like the rippling streams to which he has been accustomed. These are bordered by low, wide, and often marshy bottoms.

48. Plateau Character; the Bluffs, Rivers, Area.—This division is a plateau, sloping gently to the west. In shape it is four-sided and nearly diamond form, with Jackson near the center and Memphis in the southwest

corner. The eastern border of the division, which is but little west of the Tennessee river, is, at some points, 600 feet or more above the sea. This border nearly coincides with the dividing ridge between the waters of the Tennessee and the Mississippi, and is known as the Tennessee ridge. Thence the plateau extends to the west for 85 miles, when it very abruptly terminates, falling off in a line of steep declivities called the Bluffs, which overlook the great alluvial low plain, or bottoms of the Mississippi. The fall of the surface from the eastern border to the Bluffs is 200 feet, and the average height of the Bluffs, above the bottoms, is 130 feet.

49. The division is well veined with rivers. The most of these rise on the eastern border, and flow entirely across the plateau-slope to the Mississippi. Its lands are very generally fertile and productive.

The entire area of the division is 8,850 square miles, making more than a fifth of the State.

VIII. The Mississippi Bottoms.

50. A Low Plain; General Character, Soils, Areas, Elevation.—We have now reached, in our westerly course, the last division of the State. Entering it, we leave behind all the uplands of Tennessee, and find ourselves on a low alluvial plain which, at many points, is below the high-water mark of the Mississippi river. The division embraces all the bottom lands of the great river within Tennessee. It differs greatly from any other section of the State. Much of the area is covered by swamps and lakes; much, too, is wild and dark with heavy forests,

even now the retreat of deer and other wild animals. Other portions, confined mostly to a belt bordering the river, are in a good state of cultivation. The soils are deep and of great fertility. When its lands shall have been reclaimed, settled, and put in proper cultivation, it will be the most productive part of the State.

51. The area of the Mississippi Bottoms is 950 square miles, making it the smallest of the eight natural divisions. Its average elevation is not far from 300 feet above the level of the gulf.

CHAPTER V.

Climate.

52. Temperature, sunshine, and moisture regulate climate, but climate is modified by latitude, elevation, mountain chains and their direction, proximity to large bodies of water, the direction of the prevailing winds and the nature of the soils and rocks.

53. Mountain heights even in tropical countries are often covered by snow, which shows that height above the sea has the same effect as increasing the distance from the equator. Three hundred and thirty-three feet in height has the same effect on the temperature of a region as the difference of one degree of latitude. In the equatorial regions there are many mountain tops covered with perpetual snow. In the same latitudes the seaside is much cooler in summer and warmer in winter than the interior of the country.

54. Climate to a great extent regulates the industry of

a people. If too hot, the body is enervated and becomes incapable of hard toil; if too cold or too moist, the systematic habits of industry are destroyed by enforced idleness; if too dry, the labors of the husbandmen are not rewarded by a bounteous yield of the products of the soil. The best climate is that in which the amount of sunshine and rain, of cold and heat, is so blended and distributed as to produce what man needs for his sustenance and requires for his comfort and health.

55. Temperature.—The mean annual temperature for the State, deduced from approximate normals, the result of observations running back fifteen to twenty-seven years, is about 59 degrees; for the Eastern Division it is about 57 degrees; for the Middle Division, about 60 degrees; and for the Western Division, about 61 degrees. Average monthly temperatures are approximately as follows: January, 37.3; February, 40.9; March, 48.0; April, 59.1; May, 66.6; June, 74.5; July, 76.8; August, 75.4; September, 70.2; October, 58.0; November, 47.7, and December, 41.0. This gives a mean for the winter months of about 41 degrees; for the spring months, about 58 degrees; for the summer months, about 76 degrees; and for the fall months about 58 degrees. The lowest monthly average is in January and the highest is in July.

56. The average absolute annual range of temperature—that is, the average difference in the lowest temperature in winter and the highest temperature in summer—is about 90 degrees.

57. There are about 260 days in the year on which the temperature averages 50 degrees and above.

There is not a day in the year in which one may not do outdoor work by reason of heat or cold.

58. The mean annual temperature along a line running east and west through the center of the State is, for the

Unaka Range	45 degrees
Valley of East Tennessee	58 degrees
Cumberland Table-land	55 degrees
Highland Rim	58 degrees
Central Basin	60 degrees
Plateau of West Tennessee	61 degrees
Mississippi Bottoms	62 degrees

It will be observed that the difference amounts to 17 degrees. This is due mainly to elevation. The mean annual temperature of the Unaka Range corresponds with that of the southern parts of Canada, while that of the Mississippi Bottoms is identical with the temperature of Middle Georgia. In going from the southern boundary of the State to the northern, on the same level, there is a variation of about two degrees.

59. The Annual Temperature Compared with That of Other Countries.—The mean annual temperature of Tennessee is that of some of the most delightful regions of the globe. Its isotherms—that is, lines joining places having the same mean annual temperature—extend through North Carolina, Spain, the southern parts of France, Italy, Greece, Smyrna; cross the Caspian Sea near its southern extremity; passing on through the tea-growing districts of China and the Japan islands, and reënter the United States near San Francisco. It will thus be seen that the lines of equal heat do not correspond with the lines of latitude. Nor do they indicate an equality in climate, for,

though the mean annual temperature is the same, the variation in heat is not so great in the European States mentioned as in Tennessee. The summers of Tennessee are hotter and the winters colder. For this reason the orange, the olive, and the lemon do not mature in our climate. But for growing those plants that require a high degree of heat, such as Indian corn, tobacco, cotton, and melons, Tennessee far surpasses the countries of the same isotherms in Europe.

60. Summer Temperature and Extremes of Temperature.—The average or mean summer heat of the several divisions of the State differs more widely than the winter means. The winter means are very much the same, being about 38 degrees. The mean summer heat of the Unaka Range is about 62 degrees, making these airy heights a delightful abode during the warm weather. For the Valley of East Tennessee it is 75 degrees, which is about the same as the summer temperature of Philadelphia. The summer temperature of the Table-land is about 72 degrees, though on the edges overlooking the valleys east and west, it is two or three degrees cooler. Of the Highlands, the mean summer heat is 75 degrees; of the Central Basin, 77 degrees. West Tennessee has a summer mean about one degree higher than that of the Central Basin. The temperature, as shown by observations, rarely reaches as high as 100 degrees. The greatest degrees of cold were observed in January, 1857, 1864, 1884, and 1886; and in February, 1895 and 1899. During the last-named period the temperature ranged from 10 to 15 degrees below zero, being the lowest on record. Our coolest weather occurs generally in January; the warmest, in July.

61. Winter Temperature; Ice.—The winters are usually cold enough in the northern half of the State to secure ice. A median line drawn east and west through the State is the southern limit of domestic ice houses. South of this the ice season is too uncertain to justify the expense of constructing them. Ice sometimes, but very rarely, attains a thickness of ten inches on the northern borders of the State. Its usual maximum thickness is from two to three inches.

62. Frost.—One of the most important elements in climate is the period between killing frosts, because this measures the length of the growing season. The records show that the average intervals between the last killing frost of spring and the first killing frost of autumn are, for the Eastern Division, 170 to 180 days; for the Middle Division, 190 to 200 days, and for the Western Division, 200 days.

63. The average number of clear days in the year is 125—monthly average, 10.4 days; fair or partly cloudy days, 135—monthly average, 11.2 days; cloudy days, 105—monthly average, 8.8 days; days on which .01 inch or more precipitation occurs, 130—monthly average, 10.8. This shows a good percentage of sunshine.

64. The most destructive frosts are in April and October. From the third week in April to the middle of October the probabilities are against the occurrence of killing frosts. In the southern part of the State the period between killing frosts is twelve or fourteen days longer. This difference has an important effect upon the agriculture of the State, making cotton (except in

the mountainous division) the staple in the southern counties, and tobacco and wheat the chief products in the northern counties.

65. Precipitation.—The average annual precipitation upon the surface of the globe is about 60 inches. In the Torrid Zone it is 96, in the Temperate Zone 36, and in the Frigid Zone 12 inches. The rainfall of Tennessee (including melted snow) is just sufficient to insure a vigorous growth of vegetation, without interfering with the proper cultivation of the earth. It makes neither a wet nor an arid climate.

The average annual amount of precipitation (including rain, hail, sleet, and melted snow) for the State is about 50 inches, and is distributed as follows: January, 5.08 inches; February, 5.08 inches; March, 5.61 inches; April, 4.29 inches; May, 3.91 inches; June, 4.13 inches; July, 4.61 inches; August, 3.56 inches; September, 3.08 inches; October, 2.34 inches; November, 3.76 inches; December, 3.82 inches. This gives 13.81 inches, or a monthly average of 4.60 inches for the spring months; 12.30 inches, or a monthly average of 4.10 inches for the summer months; 9.18 inches, or a monthly average of 3.06 inches for the fall months; 13.98 inches, or a monthly average of 4.66 inches for the winter months. This shows a good distribution of rainfall during the growing and developing season, and the least during the season for gathering the fall crops, and for seeding wheat and other winter grains. The rains are generally fairly distributed over the State, and damaging droughts are rare and usually confined to limited areas.

66. Table showing the mean annual temperature and annual precipitation at the Weather Bureau Stations in Tennessee from 1871 to 1898, inclusive. The Records at Chattanooga begin January 8, 1879.

Year.	Knoxville Mean Annual Temp.	Annual Rainfall.	Chattanooga Mean Annual Temp.	Annual Rainfall.	Nashville Mean Annual Temp.	Annual Rainfall.	Memphis Mean Annual Temp.	Annual Rainfall.
1871		48.22				34.37		
1872	55.5	44.43			58.4	40.20	59.2	43.95
1873	56.6	59.39			59.5	49-47	59.0	56.20
1874	57.9	58.38			61.7	58.14	62.4	44.07
1875	55.6	73.87			58.5	53.48	59.6	56.99
1876	55.9	41.19			59.1	46.91	60.3	55.49
1877	57.4	54.35			59.9	49.64	61.1	73.50
1878	57.8	47.76			60.2	48·56	62.2	49.33
1879	51.1	48.95	60.7	52.03	61.1	57.69	61.9	52.28
1880	59.1	52.64	60.3	67.97	60.7	67.24	61.2	61.67
1881	58.7	45.67	60.8	60.97	61.2	48.08	62.5	42.84
1882	58.2	66.36	60.4	61.96	60.8	63.45	62.5	71.05
1883	57.9	50.67	60.8	54.16	59.1	58.33	61.4	57.14
1884	57.5	62.53	59.6	61.96	58.7	54.02	61.1	64.69
1885	56.4	54.70	58.4	56.61	57.4	42.95	60.5	37.41
1886	56.5	61.45	58.7	58.53	56.6	44.74	59.7	57.72
1887	58.8	42.98	60.8	51.70	59.7	48.40	62.5	42.52
1888	58.4	53.00	60.5	54.90	58.6	50.50	60.8	46.80
1889	58.4	47.73	60.4	49.31	59.1	42.01	62.2	44.67
1890	60.1	49.59	62.3	52.42	60.9	59.97	63.0	68.28
1891	58.2	46.61	60.5	58.73	59.3	52.82	61.5	51.31
1892	57.5	44.62	59.3	62.68	58.0	50.02	60.6	61.46
1893	58.0	43.42	60.0	47.46	58.7	46.30	61.3	44.45
1894	59.1	37.44	61.0	37.22	59.7	41.96	62.1	54.52
1895	57.0	38.75	58.6	46.36	57.8	42.83	60.6	38.59
1896	59.6	44.95	61.5	37.77	60.3	40.21	63.1	35.00
1897	59.1	52.95	61.0	45.29	60.4	44.03	62.8	46.03
1898	59.6	42.79	61.6	40.47	60.1	50.02	62.2	48.58

67. Snow.—The average annual depth of snow fall for the State is about eight inches. As a rule snows are light, and remain on the ground only a few days at a time, but occasionally falls of unusual depth occur, and at times the ground is covered for from two to four

weeks. These, however, are of rare occurrence. One of the earliest of these deep snows of which record is made occurred in 1840 and was thirteen inches deep, but it did not extend over the State. In March, 1843, February, 1886, December, 1886, March, 1892, January and February, 1895, snow fell to unusual depth. In December, 1886, at Greeneville and Jonesboro, in Upper East Tennessee, the aggregate depth for the month was 36 inches, and most of this fell on the 4th and 5th. In February, 1886, the fall of snow was greatest in the northwestern portion of the State, being 25 inches at Dickson, Dickson County; 24 inches at Sailors' Rest, in Montgomery County; 21 inches at Austin, Wilson County; 27 inches at Trenton; and nearly 18 inches at Nashville. The greatest falls occurred on the 2d, 3d, and 13th. The snowfall of March, 1843, was one of the greatest recorded. It began on the 5th and continued for several days, and reached a depth of 15 to 20 inches. It was quite general throughout the State even to the southern border, and it did not disappear until about the middle of April.

68. The factors of temperature, precipitation, and sunshine are so generously bestowed and so admirably distributed as to render Tennessee especially desirable as a home.

69. Winds.—Two systems of winds affect the climate of Tennessee, a *lower* and an *upper*. The lower consists of currents flowing to the north and the northeast. These come charged with warmth and moisture from the Gulf of Mexico, and give to the State a genial and

fruitful climate. The direction of the mountain ranges is such as to facilitate the passage of these life-giving breezes over the State.

The upper system embraces winds from the north and northwest, which flow above the first system, making with this a general circulation. The commingling of these two systems, brought about by changes of temperature and rains, gives rise to westerly and northwesterly winds. The easterly and southeasterly winds result from other influences apart from the general laws that govern the movements of the other winds, and may be called abnormal. The winds from the south, west, and southwest are the most frequent and the most desirable.

70. The fact has been established that the average velocity of the wind in the region which embraces Tennessee is less than in other portions of the United States. This takes Tennessee out of the path of frequent storms, giving it a delightful climate, highly favorable to the development of vegetable and animal life.

71. Variety of Natural Features.—In concluding this part it may be stated that Tennessee is remarkable for the great variety it presents in natural features. We have seen this in the number and the varied character of the natural divisions of its surface, and in its diversity of climate. It will also be made apparent in its geological formations, rocks, minerals, and soils. Nearly all the important natural features of the States around it are represented within its borders, brought together

as if by way of contrast. Thus it has, on the one hand, some of the greatest mountains of the Appalachians, with their bald summits and ancient rocks; and, on the other, the low lands, cypress swamps, and alluvial beds of the Mississippi. It has, well represented, the singular valleys and ridges of Virginia, the tobacco lands, the "barrens," and the blue grass lands of Kentucky, the orange-colored sand hills, the cretaceous beds, and cotton soils of Mississippi. And thus we might go on around and specify characteristics of Alabama, Georgia, and North Carolina, which have their counterparts within our borders. But enough has been said to call attention to the fact that *variety in natural features* is a marked peculiarity of Tennessee.

PART II.

THE ROCKS AND THE STRATA.

CHAPTER VI.

Introductory: The Soils; Geology Defined.

72. The Soils Superficial.—The soils make the well-known covering of the earth, which supplies fields for cultivation and into which the roots of plants in their natural downward growth descend. They constitute a very important but, comparatively, a very thin, superficial covering from an inch or two to ten or more feet in thickness. They are mainly of agricultural interest and are treated of in the last chapter of the book.

73. The Rocks Make the Bulk of the Earth.—Removing the soils, we find the solid earth to be made up of rocks, such as limestones, sandstones, shales, granites, and others to be mentioned. These are, in a greater part, arranged in layers or strata, terms which have been already defined. Some, however, like granite, occur not in layers but in massive, unstratified forms.

74. Definition of Geology.—To study and learn about the rocks is to study geology. The word itself is from two Greek words, and signifies *the story of the earth.* As used here, it means, in the words of Mr. Dana, "an account of the rocks which lie beneath the surface and stand out in its ledges and mountains, and of the loose

sands and soils which cover them; and also an account of what the rocks are able to tell about the world's early history."

75. Geology explains how the rocks were formed, why occurring in layers or strata, and how these, by the action of mighty forces, were raised out of the sea, elevated in mass, or folded in plaits, as if thick cloth, or broken and made to overlap, one edge upon another; and how since they have been worn or eroded by water, frost, and ice, and shaped into mountains and valleys. It points out the fact also that the strata contain the remains of extinct races of animals and plants, shells, teeth, bones, leaves, stems, and fruits, all of which has a most significant meaning. Every stratum containing these is like a leaf in a book; it is a leaf in the earth's great rock-book, a part of a veritable history, and tells about beings of strange forms that lived when the materials, sand, mud, etc., out of which the stratum was formed were accumulating at the bottom of the sea. There are many leaves in the book, and thus does geology become the record of a wonderful story.

76. Again, geology informs us about the ores and minerals, the particular rocks and the soils that man uses in so many ways in the industrial and domestic arts, and for the purposes of life, or from which he derives his means of subsistence. This part of the science is called *economic geology.*

CHAPTER VII.

Rock-Making and Other Minerals.

77. Minerals Making Tennessee Rocks.—Rocks consist of minerals. Granite, for example, is a mixture of three minerals, *quartz*, *feldspar*, and *mica*. Limestone is composed essentially of but one, *calcite*. The number of minerals entering into the composition of Tennessee rocks is not great; it is, indeed, very small, if we exclude the rocks of the Unaka Range. They are *quartz*, *calcite*, *dolomite*, and *apatite; feldspar*, *mica*, *amphibole*, *pyroxene*, *garnet*, *talc*, and *chlorite*. All but the first four are confined to the rocks of the range just mentioned. Seventeen minerals are described in the pages following, including those above and those of the scale of hardness.

78. The Ores.—The ores are minerals that can be profitably worked for the metals they contain, as the iron, lead, and copper ores. Few of them are essential constituents of the rocks. They are properly considered in Part IV.

79. In describing minerals an important characteristic is *hardness*. Minerals differ much in this, and in order to fix the degrees of hardness and have a standard for comparison, a scale of hardness has been devised.

80. The Scale of Hardness.—Mineralogists determine the hardness of minerals by comparing them with a set of selected minerals the hardness of which is known. Quartz or flint, for example, is a mineral of known hardness. It scratches glass easily, strikes fire with steel, and is therefore harder than glass or steel. Minerals are often compared with quartz in order to ascertain whether they are harder or softer. The gems, such as

the diamond, ruby, and emerald, are harder and will scratch quartz, but very many minerals are softer. Ten minerals have been selected by mineralogists as a standard of hardness, with which all minerals are compared. These make the scale of hardness. It begins with one of the softest minerals, talc, and ends with the very hardest, the diamond. Quartz, it will be observed, occupies the seventh place in the scale, and comes next before the precious stones.

81. The scale is as follows, talc being the lowest and counted one, the others following successively, showing the relative hardness by the figures prefixed:

1. Talc. Laminated green variety; easily scratched by the finger nail.
2. Gypsum. Crystallized variety; not easily scratched by the nail. Does not scratch copper coin.
3. Calcite. Transparent variety. Scratches and is scratched by a copper coin.
4. Fluor or Fluorite. Crystalline variety. Not scratched by a copper coin. Does not scratch glass.
5. Apatite. Transparent variety. Scratches glass with difficulty. Easily scratched by the knife.
6. Orthoclase. White cleavable variety. Scratches glass easily. Not easily scratched by the knife.
7. Quartz. Transparent variety. Not scratched by the knife. Yields with difficulty to the file.
8. Topaz. Transparent variety. Harder than flint.
9. Sapphire. Cleavable variety. Harder than flint.
10. Diamond. Harder than any known mineral.

The descriptions below are, for the most part, arranged in the order of the relative importance of the minerals.

I. Quartz. (Silicates.)

82. Characteristics of Quartz.—Common flint and the grains of pure, white, gritty sand are varieties of quartz. It is the material of grindstones, and of the best oilstones or whetstones. Of all the ingredients of rocks, quartz is the most common. The following are some of its char-

acteristics, and by means of these it may be distinguished from other common minerals:

1. It is one of the hardest of minerals, scratches glass easily, and strikes fire with steel.

2. It does not melt in the hottest fire.

3. It is not dissolved by water, nor by any common acid.

4. It breaks as easily in one direction as another, resembling glass in this respect.

5. It is a little more than two and a half times as heavy as water.

There are many kinds or varieties of quartz, and they present all colors. They may be thrown into three groups under the following heads: 1. Glassy or Crystallized. 2. Waxy or Chalcedonic. 3. Opaque or Jaspery.

83. (1) Glassy or Crystallized Quartz.—Quartz is often found in colorless crystals, which are frequently as clear as glass. The accompanying figures indicate the outlines of two of its crystalline forms. Similar crystals, with others of more complex forms, are found at many localities in Tennessee, especially in some of the counties of East Tennessee. Very often the crystals are attached by one end to a surface of rock, making the surface brilliant with little pyramids of quartz. At a number of points on the Highland Rim hollow balls of rock, called *geodes*, are found, which are rough on the outside, but when broken display an inner surface thickly studded with the brilliant, glassy-looking pyramids of this mineral, which sparkle in sunlight almost as if they were diamonds.

Fig. 2.

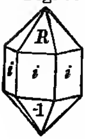
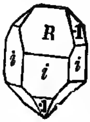


Fig. 3.



84. The region of the Hot Springs, in Arkansas, is a noted place for large and clear crystals of quartz, or *rock crystals*, and specimens are often seen in cabinets and as curiosities on mantels. Such crystals are sometimes cut and polished as lenses to take the place of glass in spectacles. They are also cut to make gems in imitation of diamonds. When the crystals are of purple color, a stone cut from them is called an amethyst; and when

yellow, *false topaz*. *Rose quartz* is simply a massive variety, colored rose-red or pink. *Smoky* and *milky* quartz are other varieties, the first having a smoky yellow or smoky brown color, and the other being milk white and opaque.

85. (2) Waxy or Chalcedonic Quartz.—Under this head are included varieties of quartz that are not crystallized or glassy. They are more like wax or rosin in structure, and often in appearance, some of them having a waxy luster and look, though of course very hard.

The word "waxy" refers to the fact that the particles of specimens of this kind are united, as is the case of glue or wax, without showing ordinarily any crystalline form, structure, or grains, such as we see in alum, rock candy, salt, coarse sugar, and in many other common substances and minerals.

Sometimes specimens of waxy quartz have their particles arranged in layers, and often of different colors, just as we might arrange layers of wax by piling one upon another. The layers may be either flat or wavy, or they may be arranged around the center (concentric) like the coatings of an onion, in which case the specimens are called *concretions*.

The waxy varieties of quartz are not so common or important as the crystallized. They do not enter largely into the composition of rocks. Some of them are interesting only as supplying ornamental stones, or as elegant material for the manufacture of small mortars for chemists and mineralogists, knife handles, seals, and such articles. When polished they present beautiful surfaces.

86. Chalcedony proper has the luster nearly of wax. Some specimens are nearly transparent, others permit the light to pass only and imperfectly through the edges, or, in other words, are translucent. Its color may be white, gray, brown, blue, or black. When of other colors it has other names. *Carnelian*, so often seen in earrings, finger rings, breastpins, and other jewelry, is a clear red or brownish-red chalcedony, the brownish kinds being also called *sard*. *Chrysoprase* is an apple-green chalcedony. *Agate* is a name applied to variegated chalcedony, presenting often several different colors. The colors may be arranged in layers or in clouds, or may be due to visible impurities. It is *banded or ribbon agate* when the different colors are in layers, whether these be wavy or concentric. If the layers are zigzag, the name *fortification agate* is sometimes used. The clouded

kinds have no very well-defined names. *Moss agate* is a variety having brown, moss-like forms distributed through the mass. *Onyx* is an agate with the layers not only of different colors, but parallel and even. It is used for cameos, the head being cut in one color, and another making the background. In ordinary onyx the layers are alternately black and white. In the *sardonyx* the layers are brownish-red or sard and white.

87. *Flint* is somewhat allied to chalcedony, but more opaque and of dull colors. It breaks with a sharp, cutting edge, as seen in gun flints. *Hornstone* is like flint, but more brittle. *Chert* is an impure flint or hornstone. *Buhrstone,* out of which mill-stones are made, is a spongy or cellular, flinty rock, which may be considered a variety of coarse chalcedony.

88. (3) Jaspery Quartz.—This is an impure colored quartz, neither crystalline nor having a waxy luster. One kind, much admired, is *Heliotrope* or *bloodstone,* a sort of green chalcedony, with spots of red jasper, which look like drops of blood. The rough surface of jasper is dull, but it admits of a brilliant polish, and is often formed into vases, boxes, knife handles, etc. Like chalcedony, it is also cut into stones for jewelry. Very fair specimens of chalcedony and jasper have been met with in Tennessee and may be obtained in the coves and included valleys of the Unaka Range.

89. Opal.—This differs from quartz in containing water in its composition. It is not as hard or as heavy as quartz. It is of various pale colors, and sometimes, as in *precious opal,* shows internally a rich play of colors. In connection with the subject of quartz it will be best to explain the terms.

90. Silica and Silicates.—Silica is the chemist's name for quartz. The two names mean essentially the same thing. Silica comes from the Latin word *silex,* which means *flint.* Silica or quartz, when analyzed, is found to be a compound of two elements, *silicon* and *oxygen*; the first a nonmetallic substance known only to chemists, the other the most abundant of all elements—a gas, and a very important constituent of the air, without which we could not live, nor could coal or wood burn.

91. Silica has the power, especially in the state of powder or fine sand, of uniting with alkaline substances, such as potash, soda, lime, magnesia, and with the oxide of iron, oxide of lead, and similar substances, to form *glass.* For example, if a mix-

ture of siliea, potash, and lime, in the proper proportions, is heated in a very hot furnaee, it will melt into liquid glass, all the different ingredients thoroughly uniting to form a definite compound. Common glass is made in this way. Such a eompound is ealled in the language of ehemistry a *silicate.* If potash and lime are used with the sand, the glass will be a *silicate of potash and lime;* if soda and lime, a *silicate of soda and lime;* and so for the other alkaline substances. Thus, by varying the ingredients, different kinds of glass are manufactured, eaeh being a different silicate.

92. Now many minerals are found in nature which have a composition similar to that of glass; in other words, they are silicates. They are generally erystallized, often in large and beautiful forms. They may be called crystallized native glasses. Such are *feldspar*, *mica*, *hornblende*, and other minerals we are soon to notiee.

93. Quartz Rock.—Great cliffs, and even mountains, are made of quartz rock. It occurs in strata and frequently in veins cutting through the other rocks. Such strata and veins, the latter sometimes containing particles of gold, are met with in the rocks of the Unaka Range.

94. Sand and Sandstones.—The beds of sand in river valleys and elsewhere are made up in great part of quartz grains, for the reason that grains of most other minerals, being soft, wear out and disappear in the washing and moving of the sands by the currents of water. *Sandstone rocks* are also composed of quartz grains; they are sometimes but little more than hardened beds of sand, the grains becoming cemented together or simply cohering. Quartz rocks differ from sandstones in not showing grains, or at least not so distinctly. They are more compact and glassy in appearance.

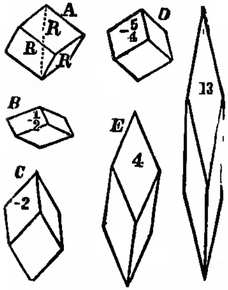
II. Calcite.

95. What It Is and How Occurring.—Calcite is, in rock form, nothing more than *limestone.* The grains of limestone rock, of marble, and of chalk are properly calcite. It does not occur, however, in rock form alone. We often find it in beautiful crystals in the cavities of the rocks and in veins, either alone or in company with other minerals and ores; it forms the curious "stony icicles" called *stalactites* which hang from the roofs of caves. It is deposited in compact layers or as a mealy material (marl) from the waters of many strong limestone springs, and it is the white substance which collects on the inside of teakettles in which limestone water is boiled. Calcite is also the principal part of oyster, snail, and other shells, as well as of many corals.

96. All rocks and substances made up of calcite are said to be *calcareous.* Limestone and chalk are calcareous rocks. Calcite itself is a calcareous mineral; it was formerly called *calcareous spar* or *calc spar. Calx* is the Latin word both for limestone and lime.

97. Crystalline Forms.—Calcite crystallizes in many forms, some of which are represented in Fig. 4 and 5. Though these

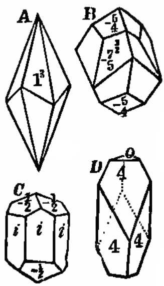
Fig. 4.



forms or crystals are so dissimilar in appearance, yet all of them break alike and easily in three different directions, always breaking, or better, splitting, out a form or block similar to A in Fig. 4. This block has six similar sides and is called a *rhombohedron* (rhom-bo-he′dron). In Fig. 4 are six different rhombohedrons, and crystals of calcite occur in the shape of every one of them. If broken, however, the pieces have the form of the rhombohedron indicated by A. A specimen of calcite in which

the crystals are flat rhombohedrons like B is called *nail head spar*, as they look something like the heads of wrought-iron nails. In Figure 5 we have other forms in which calcite crystallizes. That indicated by A is a very common form, and specimens showing the points of this form are called *dogtooth spar*.

Fig. 5.



98. Clear, transparent crystalline pieces of calcite are called *Iceland spar*. It gets the name Iceland because fine specimens have been found in that island. This spar has the curious property of making everything appear double when seen through it. In place of one letter, line, or dot we always see two. The crystals are much used in studying the subject of light.

99. Chemical Character.—Calcite is, in chemical language, *carbonate of lime* (calcic carbonate); that is to say, it is a compound of *carbonic acid*, which is a gas in the free state, and *lime*. If calcite, either in crystals or in its rock forms, is heated red hot, as limestone is heated in a limekiln, it is decomposed, the *carbonic acid gas* being driven off in the air, and the *lime* remaining. Carbonic acid may also be driven off from calcite or limestone by a stronger acid, such as hydrochloric (muriatic) acid, nitric acid, or even strong vinegar. In this case what remains is not lime, but a compound of lime with a part of the acid.

100. If a drop of acid, which (if hydrochloric or nitric) ought to be diluted, is placed upon calcite or limestone, a brisk boiling or bubbling takes place at once in the drop, owing to the escape of the carbonic acid gas. This boiling is called *effervescence*. The experiment is a simple and useful test by which calcite may be distinguished from a number of minerals which it resem-

bles. It will, for example, distinguish calcite from quartz or gypsum; it effervesces with an acid, while they do not.

101. Calcite is dissolved to a limited extent in water containing free carbonic acid. Rain water, in passing through the air, absorbs some carbonic acid, and acquires the power of dissolving limestone. Such water, passing through the soil and coming in contact with limestone or other calcareous material, dissolves some of it, and when it issues in springs from the rocks or soils is *hard* or *limestone water*. A vast amount of limestone rock is thus dissolved and carried away every year by the water of springs.

102. Caves.—The caves so common in limestone regions owe their origin in most cases to the action of rain water containing carbonic acid. This gets into the cracks and fissures of the rocks and dissolves out a way for the water to run. Thus an underground stream is formed. Such streams, once started, not only dissolve the rock, but wear and scour it away with the sand and mud which they often carry along. Thus large and long subterranean caverns have been excavated, like the *Big Bone*, *Dunbar's*, and other caves in Tennessee, and the *Mammoth Cave* in Kentucky.

103. Stalactites and Stalagmites.—The rain water which trickles down through the cracks and fissures in the roofs of caves contains dissolved limestone; it brings a load of limestone or calcite with it. Upon reaching the ceiling of the cave, a part of the water is evaporated, and calcite is deposited upon the ceiling. In this way stalactites, to which we have already referred, are commenced and are made to increase. There may be nothing but a little knot or ring of matter to begin with, but by continued additions the stalactite may become

very large and long. Some of the water falls to the floor of the cave, and, evaporating there, deposits calcite in various forms. Thus it is that often stump-like piles of calcareous matter are built up, which are known as *stalagmites.* A stalactite often has a stalagmite directly under it. The first lengthens downward from the ceiling, and the other upward from the floor. They often meet and form a column or pillar in the cave.

104. The waters of springs and rivers sometimes deposit calcite from solution in considerable beds. When these are extensive and compact, the material is known as *travertine;* when cellular, as *calc* or *calcareous tufa.* These are of the same nature as stalactite and stalagmite material. Calcareous tufa often contains twigs, leaves, moss, etc., which have become enveloped by the deposition of the calcareous matter around them. Travertine is frequently used as marble, and some varieties are very handsome. The so-called Mexican onyx is a variety of travertine.

III. Dolomite.

105. Compared with Calcite. Magnesian Limestone. — Dolomite is much like calcite, from which it is not always easily distinguished. It is harder than calcite, and does not effervesce freely unless the acid is heated. As to chemical constitution, dolomite contains not only *lime* but *magnesia* also; so that while calcite is simply carbonate of lime, dolomite is *carbonate of lime and magnesia.* Dolomite is often burned for lime; when it is, the lime produced is necessarily mixed with magnesia.

106. In rock masses this mineral is called *magnesian limestone.* Great strata of it, many hundred feet thick, exist in Tennessee, especially in the eastern part of

the State. The higher and greater part of Knoxville is built upon this rock.

IV. Apatite.

107. The Mineral of "Phosphate Rocks," and How Differing from Them.—This mineral has within the past few years assumed great importance in Tennessee. It is the mineral or the characteristic mineral substance of thé "phosphate rocks" so extensively mined in Maury, Hickman, and other counties. Its massive forms are to be distinguished from the ordinary phosphate rocks. The latter occur in beds or strata, like sandstones or limestones; while the former are met with in amorphous, shapeless masses, somewhat like the stalagmitic masses (travertine or calcareous tufa) met with on the floors of caves, or found in deposits on slopes below highly calcareous springs.

108. Occurrence and Characteristics.—Apatite, in its massive forms, is found in commercial quantities in Perry county. Small quantities have been seen in other counties, associated with the stratified phosphates. In some mineral regions, as in North Carolina and California, it occurs in beautiful crystalline forms, which are often six-sided. A yellowish-green kind is found in Canada which is known as *asparagus stone.*

109. In some points apatite resembles calcite, but is two degrees harder, being 5 of the scale, while calcite is 3; it is also heavier, having an average specific gravity of 3, while the average calcite is 2.6. It is slowly soluble in nitric acid without effervescence.

These facts are important because they help to distinguish phosphate rocks from limestones. Apatite may be almost of any color from white to brown. Much of the Perry county mineral is white, variegated with yellow, red, and violet, and is often of handsome appearance.

110. Chemically, the mineral is a lime phosphate, or better a calcium phosphate; that is to say, is composed of phosphoric acid and calcium, the metal of lime. It sometimes contains a little of the elements fluorine and chlorine, one or both. In composition it greatly resembles thoroughly burned bones.

V. Feldspar.

111. Compositions and Kinds.—This is one of the minerals which form granite and granite-like rocks. Within Tennessee it is only to be found in the rocks of the Unaka Range. There are several varieties of feldspar; or rather, feldspar is the name of a *group* of minerals. They are all silicates of alumina, combined, in addition, with some other alkaline substance. One variety, orthoclase, already mentioned as a member of the scale of hardness, contains potash, and is therefore a *silicate of alumina* and *potash—a potash-feldspar.* This is common feldspar. Another contains soda in the place of potash and is known as *soda-feldspar* or *albite.* Others contain both soda and lime and are *soda and lime feldspars*, one of which is known as *labradorite.* These minerals have about the same weight as quartz and calcite.

112. Distinguished from Quartz.—The feldspars may be distinguished from quartz by the following characteristics:

They are not so hard by one degree, though they cannot be scratched by the knife; they melt when exposed to high heat; and they break or split in two directions, in one direction especially splitting easily, and giving an even, bright, and polished surface.

113. This property of splitting in one or more directions, with bright, even surfaces, is called *cleavage* by mineralogists. Very many minerals show it. We have spoken of the cleavage of calcite on page 44. Quartz does not ordinarily show cleavage.

114. Source of Clay.—The feldspars are important minerals. It is from them principally that the characteristic ingredients of the different clays have been and are derived.

115. The pure clays are *hydrous* (containing water) silicates of alumina. When feldspars, or the rocks containing them, decompose, they lose much of their basic part—that is, their potash, soda, lime, etc.,—becoming simply silicates of alumina, or clays. *Kaolin*, or China clay, is one of the purest of the clays. It is found in regions where granite-like rocks are decomposing. The best China ware, or porcelain, is made from it.

116. Common clays are mixtures, and contain sand, oxide of iron, and minute particles of other minerals derived from various rocks.

VI. Mica.

117. Characteristics, Uses, Etc.—This mineral, sometimes improperly called isinglass, is easily recognized by its splitting or

cleaving into exceedingly thin and elastic leaves. It is often seen in granite, sandstones, and other rocks, in minute silvery and sometimes shining black scales. It is one of the trio of minerals which compose ordinary granite, quartz and feldspar being the others. When the granite is coarse the leaves of mica are large and may be mined. There are mica mines in North Carolina. Mica leaves stand the fire well, and are used for a variety of purposes, one of which is to make windows in stoves, so that the fire may be seen.

118. Mica is generally transparent or translucent, and may be white, gray, brown, or black. It is not quite as hard as calcite. It is, like feldspar, a *silicate of alumina*, combined in various proportions with alkaline or basic substances, principally potash, magnesia, and oxide of iron. Some varieties contain water as an ingredient.

VII. Amphibole and Pyroxene.

119. Common Characteristics.—These minerals have the same composition. They are silicates of two or more of the following bases: lime, magnesia, oxide of iron, and alumina. Rarely, certain other bases occur. Lime and magnesia are generally present in the different varieties, of which there are very many. Amphibole (am′phi-bole) and pyroxene (pyr′ox-ene) are often distinguished with difficulty unless in crystals, the shapes of which are unlike. In their different varieties they vary in color from white through shades of green to black. They may be in crystals or crystalline masses, or in grains, leaves, or fibers. Some of the fine, fibrous, or silky kinds of both are called *asbestos*. These minerals vary in hardness from 5 to 6½, and are therefore not as hard as quartz. They are from three to three and a half times as heavy as water.

120. Amphibole.—This is often called *hornblende*, but we confine this name to the dark green or black varieties; hornblende contains iron and alumina. It frequently takes the place of mica in granite and allied rocks. It often looks like mica in the

rocks, but it is brittle, and will not split into thin, elastic scales with the point of a knife as mica does. It is a common mineral at the Ducktown copper mines.

121. Pyroxene.—A greenish variety of this mineral, called sahlite, is found in Tennessee. It is associated with the magnetic iron ore of Carter county. Augite is a black or blackish-green variety, looking like hornblende. It contains iron, and is common in rocks of igneous origin.

VIII. Garnet.

122. Characteristics.—Beautiful, many-sided, dark-red crystals of garnet occur imbedded in mica slates and other rocks. They may be found in the region of the copper mines at Ducktown.

Fig. 6.

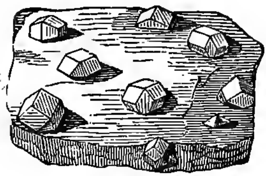


Figure 6 shows the manner of their occurrence, as well as how they project out on the surface when the rock has been worn away by the weather. The crystals are of all sizes from that of a pin's head to forms an inch or more through. This mineral is also a *silicate*, containing alumina, iron, and lime. It is variable in hardness, but averages about that of quartz. When found in well-colored and clear crystals it is used as a gem.

IX. Tourmaline.

123. Tourmaline is another mineral which is found imbedded in rocks. It occurs usually in long, black, brilliant prisms. Sometimes its crystals are beautifully red or green. The red variety is occasionally used to imitate rubies. Tourmaline is a *silicate* much like the others, but differs in containing boracic acid, one of the ingredients of common borax.

X. Talc.

124. Talc.—This is one of the softest of minerals. It represents 1 in the scale of hardness. It is unctious or soapy to the touch,

so much so that the powder is sometimes used like grease and graphite as a lubricator. It is not unfrequently called *soapstone.* It is greenish, white, red, or gray, and has a pearly hue or luster. One variety splits into thin leaves like mica, but the leaves are not elastic; they bend but do not fly back, which serves to distinguish them from mica. Talc is a silicate of magnesia containing water. This mineral is sometimes used as pencils for slates.

125. Steatite is an earthy, compact variety of the mineral. It is sawn into slabs and used for lining furnaces and stoves as a protection against heat, and has also other uses. It is mined in North Carolina. Talc has very nearly the weight of quartz, bulk for bulk.

XI. Chlorite or Prochlorite.

126. Chlorite is mnch like talc, and sometimes the two are not easily distinguished. It is slightly harder than talc, not so unctious to the touch, and generally of a darker green color. It contains also alumina, in addition to the other ingredients of talc.

Both of these minerals enter largely into the composition of rocks. They form talcose and chloritic slates.

XII. Serpentine.

127. Like talc, serpentine is a hydrous silicate of magnesia. It is, however, a different mineral. Its average hardness is about that of calcite, with which it is sometimes associated as a massive rock. This rock, when containing veins of calcite and sawed into slabs, makes a much-admired marble called *verd antique* marble. The serpentine may be green, yellow, or red, and with the white calcite it makes a mottled or clouded surface, often of great beauty.

XIII. Topaz.

128. Topaz is a silicate of alumina. Its clear crystals have a rich luster and belong to the class of precious stones. They have extensive use in jewelry. The characteristic color is yellow.

XIV. Sapphire and Alumina.

129. Sapphire is crystallized alumina, and alumina belongs to the same class of substances that lime does; that is to say, it is alkaline or basic, though very feebly so. Like lime, it unites with silica or quartz to form native glasses or silicates; and topaz, just mentioned, is one of them. Alumina is the characteristic constituent of common clay, the clays being compounds of alumina and silica, with which, however, there is combined more or less water.

130. The name *sapphire* is properly applied to the blue crystals of alumina. The *red* crystals are called *rubies;* the green, *oriental emeralds;* the violet, *oriental amethysts;* and the yellow, *oriental topazes.* These stones are next to the diamond in hardness and have very great value.

A more common name for crystallized alumina is *corundum.* This name includes all the varieties, whether in handsome crystals or not. Sapphire and other forms of corundum are found in North Carolina not very far east of the Tennessee line.

The common sorts of corundum, when reduced to coarse and fine powders, are sold as *emory.* These, on account of the hardness of the mineral, have great scouring and polishing properties.

XV. Diamonds.

131. The diamond is crystallized carbon. There are three very different forms of carbon; one is seen in common charcoal, another in the misnamed "*black lead*" of cedar pencils, and the third, in the *diamond.* The "*black lead*" of pencils contains no lead. The proper name of it is *graphite*, from a Greek word, which means "I write." It is a soft, black mineral, very suitable for writing on paper—a use of it known to every schoolboy. It is also used for polishing stoves, as a lubricating material in the place of grease for the axles of wagons, and for other purposes.

It is truly wonderful that a single substance like carbon can thus form three things so very different. Graphite is as soft as

talc, which is only one in the scale of hardness, while the diamond is 10, or the very hardest of the scale. Charcoal is quite different from either; it burns easily, while graphite and the diamond burn with great difficulty.

XVI. Gypsum.

132. Gypsum is the second member of the scale of hardness, and, in many respects, is an important mineral. Chemically, it is sulphate of lime (calcium sulphate) combined with some water. When ground up it is the "land plaster" used by farmers to fertilize land. When pulverized and heated enough to drive out the water it contains, it becomes the "plaster of Paris" used by dentists and others for making casts, and by plasterers for giving a hard finish to walls. Its color is usually white, but may be red, yellow, or even black. It occurs sometimes in the cavities and fissures of limestone rocks, often beautifully crystallized. A transparent, crystallized variety, which splits easily into thin plates, is called *selenite.*

133. In some of the States gypsum occurs massive as a solid rock. A noted locality is near the Tennessee line in Virginia. Beautiful cabinet specimens of it are found in cavities of the limestones of Tennessee. Solid, massive, translucent gypsum is known as *alabaster.* Being easily cut by tools, it is worked extensively into images and ornamental objects.

XVII. Fluor or Fluorite.

134. Fluorite is fourth in the scale of hardness. It is a compound of the elements *fluorine* and *calcium,* and is often found in handsome crystals and crevices of

limestone rocks. It is named *fluorite* (flow-stone), for the reason that it is used sometimes, where abundant enough, as a flux in the reduction of the ores of metals. Its color is various—white, yellow, purple, and green—presenting usually bright and pleasing shades. It is the chief source of the acid gas which is used for etching writing and ornamental designs into glass. The compact forms of it are cut into vases, urns, and other tasteful forms, which are more prized than those made from alabaster.

CHAPTER VIII.

The Kinds of Rocks.

Having considered the minerals which enter into the composition of Tennessee rocks, we may now take up the rocks themselves.

135. The Origin of the Rocks.—Tennessee rocks, with but few exceptions, were once either beds of gravel or sand, or else were beds of calcareous or clayey muds, lying at the bottom of the ocean which, in certain times past, covered the whole country, and, at other times, but parts of it. The gravel, sand, and mud were derived from a variety of sources. They were washings from the lands, or matter drifted from one part of the ocean to another, or accumulations of shells, corals, and other remains of animals and plants, broken, or even ground, to mud by the currents. The beds, by the pressure of the waters and their own weight, became

compact, and finally, through simple cohesion or the action of cementing substances, hardened into rock. Thus the pebbles became conglomerates; the sands, sandstones; the clays, shales; the calcareous mud, limestones.

136. Deposits of materials like those which ages ago gave origin to the rocks of Tennessee are at this day accumulating and hardening, more or less, into rock in the oceans and seas, and some of them may in time to come *be raised out of the sea, as our rocks have been*, to form the foundations of new lands for future generations.

137. It must be stated, however, that, so far as the *hardening* of the beds is concerned, the greater part of *West Tennessee* presents an exception. Here the strata are unconsolidated beds of sand, clay, and gravel. These sands and clays were deposited, like the others (but long afterwards) at the bottom of the ocean, or rather of an arm of the ocean, which reached up as far north as the mouth of the Ohio river. This arm was an extension of what is now the Gulf of Mexico. Such strata as those of West Tennessee, although not hardened, are, nevertheless, called *rocks* by geologists.

138. But it must not be understood that the deposits which were the beginnings of our rocks were beds of pure sand, clay, or calcareous mud. Washings from the lands and drifts in the ocean would contain everything movable by floods or currents. The different mineral matters would be sorted out to some extent by the flowing water, so that here pebbles would predominate; there, sand; and beyond, clay. But yet this sorting would not be complete; each kind would generally contain

more or less of the others. It thus happens that sands and sandstones often contain clay, calcareous matter, grains of mica, and other minerals. We call it sandstone when the sand predominates and gives character to the mass. Limestones are rarely pure calcareous matter; they may contain sand, clay, and other ingredients in various proportions. This is one reason why we have so many varieties of limestone. And so with the other rocks.

139. The rocks in general may be grouped into three classes—the *sedimentary*, the *metamorphic*, and the *igneous;* or, in familiar terms, the *sediments*, the *altered*, and the *fire-formed.*

140. I. Sedimentary Rocks and the Terms Applied to Them.—The beds of sand and clay of which we have spoken, and similar deposits, are often called *sediments*, and the rocks resulting from them *sedimentary* rocks. The term *fragmental* is also applied to them, for the reason that the particles from which they are made are *fragments* from still older rocks. They are also called stratified rocks, as the materials of the sediments were spread out in layers one above another. Many of them contain *fossils*, and are therefore termed *fossiliferous* or *fossil-bearing* rocks. The sedimentary are, by far, the most abundant rocks in Tennessee.

141. II. Metamorphic Rocks.—*Metamorphic* means *changed.* In some regions sedimentary rocks have been so acted upon by long-continued but not a melting subterranean heat as to have changed in mineral character. The water-worn particles or fragments originally composing them are seen, if large enough to be visible, to have become crystalline grains. Very often, under the influence of heat, the elements of the particles react upon each other in such ways as to produce crystalline grains of minerals

very different from the species of minerals to which the particles belonged. By such changes impure sandstones and clayey rocks have been, in some regions, transformed into granite-like rocks wholly different in appearance: dark and purer limestones into white statuary marble, and soft shales into tough roofing slates. Rocks thus changed are known as *metamorphic* rocks. Many of the strata of the Unaka Range are of this character.

Sometimes metamorphic rocks show no distinct crystallization, the change consisting in a greater hardening of the original mass.

142. III. Igneous Rocks.—The rocks so named have been in a melted state. They occur in what were once openings or fissures in the earth. The fluid rock, coming up from some seat of fires below, filled the fissures and solidified in them. In this way a class of veins have been formed which are called *dikes*. Many dikes have been observed in the oldest rocks of the Unaka Range. In volcanic regions igneous rocks are common; they occur in dikes and beds, the latter resulting from the overflow of lava from volcanic vents or craters.

We shall now enumerate or briefly describe the rocks occurring in Tennessee.

143. (a) Sandstones and Related Rocks.—Sandstone is one of our most common rocks. It appears in many parts of the State, and in most of the formations. It may be fine or coarse grained, and of a variety of dull colors—white, gray, brown, or red. When hard and rough, it is sometimes called a *grit;* if containing clay or earthy matter, it is *argillaceous sandstone*, *argilla* being the Latin word for *clay.*

144. In the Unaka Range sandstones are met with which are hard, very compact, gray or white, and consist of quartz grains. These are sometimes called quartz-

ites. They are either partly or wholly metamorphic rocks. Some varieties contain scales of mica.

145. Pebbles and Breccia.—A bed of gravel which consists of rounded pebbles mixed with sand, when consolidated into rock, is called a *conglomerate* or *pudding stone.* If the gravel contains angular (not rounded) fragments, the rock resulting is *breccia* (bret′cha). The pebbles or angular fragments are not always quartz. Sometimes they are limestone (calcite) or of other kinds. If principally quartz, the rock is *siliceous conglomerate,* or *siliceous breccia,* as the case may be; if of limestone, *calcareous* or *limestone conglomerate.* If the pebbles or fragments are cemented together with iron ore, the rocks are said to be *ferruginous,* a term derived from a Latin word which means *of iron,* or *containing iron.*

146. (b) Limestones. — Common limestones are well known. The characteristic mineral contained in them is *calcite*, and hence they are called *calcareous* rocks.

There are many varieties of limestone. They may be coarse or fined grained, hard or soft, pure or impure as before explained; they may contain shells entire or broken, crinoids, corals, fish teeth, bones or other relics of extinct races. They are generally dull-blue or gray, but may be colored, by the impurities present, yellow, red, brown, and even black.

147. The following are common varieties:

Argillaceous limestone, containing clay.

Siliceous limestone, containing fine sand, or siliceous particles.

Cherty limestone, a limestone more or less mixed with the kind of flint called *chert,* which is present in particles, lumps, or layers.

Phosphate limestone, a limestone rich in phosphate material.

Oölitic limestone, or *egg limestone,* made up of small round

particles (concretions), from the size of a mustard-seed to that of a pea, and looking like a mass of petrified fish eggs. *Oölitic* is derived from a Greek word meaning egg.

Shell limestone and *fossiliferous limestone*, containing animal remains.

Chalk, an earthy limestone, generally white, easily making a mark on wood or other hard substance.

Hydraulic limestone, an impure limestone that burns into a kind of lime which hardens under water; it is also called *cement limestone* and *water-lime* rock.

Marl, an earthy mass, containing much soft or powdery limestone.

Marble. Any limestone that is durable, takes a good polish, and looks well when polished, may be called *marble*. The marbles of Tennessee will be treated of in the Economic Part.

148. If not too impure, limestones burn easily into lime. Sometimes, when containing much sand, flint, or clay, they burn into lime with difficulty; they are then called *fire rocks* in Tennessee, and are used for hearths and the backs of fireplaces.

149. The limestones of this State belong to the sedimentary class. In North Carolina, and not far from the Tennessee line, limestones exist which have been changed by heat into more crystalline, compact, and generally lighter-colored rocks, or, in other words, are of the *metamorphic* class. Some of these make good marble.

150. The calcareous matter out of which the *stalactites* of the caves are formed (p. 46) is another kind of limestone not included above. It differs in having once been *dissolved in water*, as already explained, while common limestones were at one time beds of calcareous mud, or sediment, that have since consolidated into rock.

151. (c) **Magnesian Limestone, or Dolomite.**—This rock is

much like limestone, and is often so called. It has been sufficiently described under *Dolomite Considered as a Mineral.*

152. (d) Iron Ore Rocks.—The *dyestone ore* of Tennessee is a stratified rock. It appears to have been once a mixture of limestone and carbonate of iron (*a double carbonate*). The part worked for iron has had the limestone leached out of it by the action of water, and has been further decomposed so that now it is mainly a red *hematite.* Other beds of hematite in East Tennessee and the *magnetite* of Carter county are also rocks. *Limonite* is an important ore of iron, but can hardly be included here, as it is not properly a stratified rock. For descriptions see Economic Part.

153. (e) Shale.—This is another very common rock. Shales are hardened beds of clay; some shales are little else than clay arranged in thin laminæ, or leaves. They belong to the sedimentary class. Shale is often improperly called *slate*, especially if splitting into plates a foot square or more. There is, however, no true slate anywhere in Tennessee east of the Unaka Range, where the metamorphic rocks are found. Many rocks, so called, are shales.

154. Shale is a soft rock, splitting or separating, like slates, into thin leaves, which are generally fragile or easily broken, but sometimes quite tough. It may be gray, greenish, purplish, reddish, and even black. The following are included among the varieties:

155. Bituminous Shale.—A shale containing *bitumen*, or coaly matter, and sometimes yielding crude coal oil, or kerosene, when heated in a still. It is generally black, and when put on hot coals often flames for a little while, but does not burn to

ashes. It is often mistaken for coal. Bitumen is a sort of natural pitch or hardened tar.

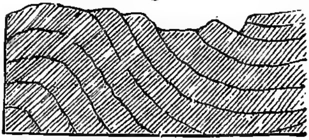
156. Alum Shale.—A shale from which alum may be manufactured. It contains alum or iron *pyrite*.

Some soft shales are improperly called soapstones.

157. (f) Slate.—The true slates are rocks which have been changed by heat, and belong, therefore, to the metamorphic class. They are slaty in structure, being made up of laminæ of greater or less thickness. The slates, as we have said, and all the rocks that remain to be described, are confined to the Unaka Range, the metamorphic area. Some of the principal kinds are:

158. Clay Slate, or Argillite.—*Roofing slate and writing slate* are good examples of this kind. Clay slate, or argillite, is a slaty rock of fine grain and of various, but usually dull, colors, such as gray, green, red, purple, and black. It must split evenly to make good roofing and writing slates. Slabs of it are used for table tops and for mantles. It is usually a mixture of very fine quartz and feldspar. This rock differs from shale, among other things, in the direction in which it splits. Shale splits in a plain parallel to the top and bottom of the bed or stratum to which it belongs, while slate splits independently of the bedding, and may split directly or diagonally across the bed. The cut (Fig. 7) illustrates this. The strata, which in this case are curved, are marked out by the curved and darker lines; the slates by the finer, straight, and diagonal lines. It is seen that the slates run in a determinate direction without reference to the bedding. This kind of splitting is called *slaty cleavage*.

Fig. 7.



Argillite not infrequently contains imbedded in it crystals of pyrite, garnet, and other minerals.

159. Mica Schist.—*Schist* is another name for slate. The name is applied to a slaty rock mostly made up of visible, glistening scales of mica. Mica schist is very slaty in structure, breaking into thin pieces and often easily wearing away. Besides the mica, it contains a little feldspar and more quartz. Like argillite, it often contains imbedded crystals.

160. Mica Slate.—This is like mica schist, excepting that the scales of mica are so small as hardly to be seen without a magnifying glass.

161. Hydro-Mica Slate.—Similar in character to mica schist and mica slate; but the mica is *hydrous*—that is, contains water in composition, which gives the rock a more or less greasy feel and a pearly look. It was once called talcose slate, the hydrous mica being taken for talc.

It may be added here that there is a true talcose slate, but it occurs rarely and in local beds. *Steatite* or *soapstone* is a rock form of talc, unmixed with other materials.

162. (g) Granite.—This rock in some countries forms great mountain masses. In Tennessee there is very little of it, the rock so called being gneiss, which is described below. It differs from all the rocks we have mentioned in not occurring in beds or layers; it is a massive, *unstratified* rock. Granite, as before stated, is composed of *quartz*, *feldspar*, and *mica*—minerals that have been studied. These exist in granite, not in rounded grains or in pebbles such as make up sandstones and conglomerates, but in crystalline grains, those of feldspar and mica often showing smooth and shining faces. The grains are promiscuously mixed together.

Granite is of motley color, each of its minerals having usually a different tint. On broken, or better polished, surfaces the quartz grains or portions, in a given speci-

men, may show spots of either gray or smoke color; the feldspar, white or flesh-red, and the mica, white or brown or even black.

163. (h) **Syenite.**—When a granite-like rock is deficient in quartz and has the mineral hornblende in it, in the place of mica; it is called syenite.

The hornblende in syenite is generally dark-colored or black, sometimes grayish or greenish black. Its grains are crystalline, but will not split into thin, flexible scales like mica. In this way it may be distinguished from black mica. This suggests a way of determining whether a given rock is granite or syenite.

The red "Scotch granite" brought to this country for monuments is syenite.

164. *Unakite* is a coarse granite in which a greenish mineral called *epidote* replaces mica. This rock is found on the North Carolina line, in Cocke County, Tenn., at a place called the "Bluff." It has been named *Unakite* because it occurs in the Unaka mountains.

165. (i) **Gneiss.**—Gneiss (pronounced like the word *nice*) is the same as granite, excepting that it occurs in beds or layers, and looks like a stratified rock. It has been called *stratified granite.* It occurs in layers because the minerals composing it, especially the mica, are arranged in planes. The rock will sometimes break rather easily into slabs or flags. Many of the high mountains of the Unaka Range, near and on the North Carolina line, are made up of gneiss and gneissoid (nice′soid) rocks.

Gneiss passes into *mica schist* or *mica slate* when the amount of mica present becomes great in proportion to the feldspar and quartz, the other ingredients of the rock.

166. In gneiss, mica schist, and mica slate, as in granite, the mica may be replaced by hornblende. Hence we have *hornblende gneiss*, *hornblende schist*, and *hornblende slate*.

167. *Protogine* is a sort of granite or gneiss containing *chlorite* (or *talc*) in place of all or some of the mica.

Many of the mountains near and on the North Carolina line are made up of gneiss and gneissoid rocks, principally of the mica and hornblende kinds.

168. The rocks just described, commencing with *slate*, are included in the metamorphic series. Granite occurs sometimes in veins and *appears* to have filled fissues in a melted state. Such granite has *been called* an *igneous* rock, but the matter of which it is composed may have been brought into the fissures through the agency of heated waters, or in some other way.

169 (j) **Trap Rocks.**—These are igneous rocks, which, with the lavas, as before remarked, are, so far as Tennessee is concerned, comparatively unimportant.

Trap (from *trappa*, "step") is a heavy, dark-colored rock, often found in *dikes*, or filling what were once fissures in the crust of the earth. It entered these fissures from fiery depths when in a melted state.

Dikes are met with in many regions where there are no volcanoes, so that trap is not necessarily a *volcanic* rock. It consists of a *lime-soda feldspar* (called from *Labrador*, where it was first found, *labradorite*) and *augite* (pyroxene). It also contains grains of magnetic iron ore. The rock is crystalline in texture, but sometimes very finely so, being hard and compact.

170. Trap is the rock of the long bold cliff on the west side of the Hudson river, just above the city of New York, and well known to travellers as the *Palisades*. Layers and masses of trap

make many ridges in the States bordering on the Atlantic from Massachusetts to North Carolina, as well as the region of Lake Superior. It is the rock of the Giant's Causeway, in Ireland, and of Fingal's cave, in the isle of Staffa, illustrations of which places are often seen in school geographies. Roan Mountain in Tennessee is very much cut through or intersected by dikes of trap rock.

171. *Dolorite* and *basalt* are names applied to trap rocks; basalt especially to the fine-grained varieties.

Diorite (Greenstone) is a trap-like rock, composed of a soda feldspar, or a soda-lime feldspar and hornblende.

Amygdaloid or *Almond-rock*, is a trap containing, imbedded in it, nodules of different minerals. The places filled by the nodules were originally cavities in the trap made by the gases, when the rock was still melted. Sometimes the nodules have the shape of almonds, hence the name of the rock, *amygdalum* being the Latin word for *almond.*

172. Porphyry.—Any rock containing distinct crystals of feldspar scattered through it is said to be *porphyritic.* A polished surface of such a rock shows angular spots on a ground of different color. True *porphyry* has both spots and ground of feldspar, though differently colored. It consists of compact feldspar, through which are disseminated crystals of the same material.

173. (k) Lavas or Volcanic Rocks.—The rocks so named have been formed by the action of volcanoes. These fire mountains eject melted rock from their craters, and sometimes from fissures and openings on their sides. The melted matter cools and hardens into lava of different kinds.

174. The lavas are much like trap in composition. They are often cellular in structure, and many of them resemble slags from furnaces.

Trachyte (from a Greek word meaning "rough") is a common lava, which, when broken, shows a "rough" surface. Another variety, *scoria,* is light and spongy. *Pumice* is also spongy, but the cells are long and the rock fibrous in appearance. Pumice is from an Italian word meaning "froth." It is usually of a whitish-

gray color, and is extensively used for scouring and polishing wood, stone, metal, glass, etc. *Obsidian* is a volcanic glass, formed by the rapid cooling of certain kinds of melted lava.

CHAPTER IX.

How the Rock-masses Occur; Their Condition and Fossil Remains. Geological Theory of the Earth.

I. Forms in Which Rocks Occur.

175. Forms and Classifications.—There are three forms in which the rocks occur: (*a*) the *stratified;* (*b*) the *unstratified;* (*c*) the *vein form.*

The above is a classification of the rocks, based on their forms as actually seen in cliffs, ledges, quarries, veins, wells, and other exposures, without especial reference to the theories of their origin, or to the agents concerned in forming them, though these may be noticed in the descriptions.

The *first* classification given (that on page 58, in which the rocks are grouped into three classes, *sedimentary, metamorphic,* and *igneous*) is different and has direct reference to these agents, and especially to the two great and opposing agents, *water* and *heat,* which, more than all others, have been instrumental in building up, changing, destroying, and rebuilding the rocks of the earth. The sedimentary rocks, as we have learned, owe their form to the agency of *water;* the metamorphic, to that of *water* and *heat;* the igneous, to *heat* or *fire.*

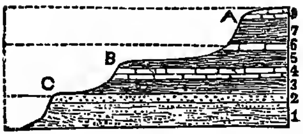
176. (a) The Stratified Forms.—These forms have been spoken of already, and the definitions, severally, of *layer, stratum,* and *formation* given on page 3, to which the reader is referred.

Very nearly all the rocks of Tennessee are stratified. The fact that the rocks show themselves in layers must

be familiar to every boy or girl who knows how to observe. It is well seen in the bluffs (cliffs) along the rivers; limestones, sandstones, and other rocks are quarried out *in layers* of different thicknesses; *layers* of rock are seen in the beds of creeks, in railroad cuts, and often outcrop on the hillsides. Many rocks, as the shales, slates, and schists, we have studied, and are made up of layers so thin as to be called *slaty*.

177. The annexed figure (taken with others which follow, from Mr. Dana's "Manual of Geology") may be used as an illustration of how the layers and strata of rock show their edges or *outcrop* on the face of a bluff.

Fig. 8.



In the particular series of strata represented, 1 at the bottom is a stratum of sandstone; 2 is a hard gray layer, called Gray Band; 3, a thick bed of greenish shale; 4, limestone; 5, another bed of greenish shale; 6, another stratum of limestone; 7, shale again; 8, at the top, another limestone, different from those below. The thickness of the whole is 400 feet.

178. Such an exhibition of the rocks is called a *section*. The cut represents a section of the strata exposed along the Genesee river at the falls near Rochester, N. Y. It is a good type of many found in Tennessee. Whereever the rocks are cut into or through by streams, railroads, or mining, sections of the layers or strata are exhibited.

The part of the cut on page 73, showing the edges of the strata, a, b, c, etc., is a great cliff, and gives a good idea of what is meant by a section in geology.

179. In the deep gorges of mountain streams, the sections presented are sometimes thousands of feet deep. The Colorado river, on the west slope of the Rocky mountains, has, for 200 miles *of its course*, cut its way down through the strata for hundreds, and even thousands, of feet. Looking up from the river, the cliffs rise, on both sides, in vertical walls from 3,000 to 6,000 feet in height. The layers and strata are well exposed in these cliffs and on so large a scale that geologists delight to visit them.

180. In our own State, the grand cuts formed by the rivers intersecting the Unaka Range, and spoken of on pages 15 and 16, give sections of rocks hundreds of feet high. The Cumberland Table-land also has many gorges (gulfs, we sometimes call them) worked out by the streams and exposing the strata which build it up. The strata of the Highland Rim are exposed in a similar manner. Many of the streams which flow from this Division have cut out, in their descent into the Central Basin, deep gorges bounded by high, bold cliffs. At the heads of the gorges are often beautiful, and even grand, water falls. Those of the Caney Fork and its tributaries are especially noted.

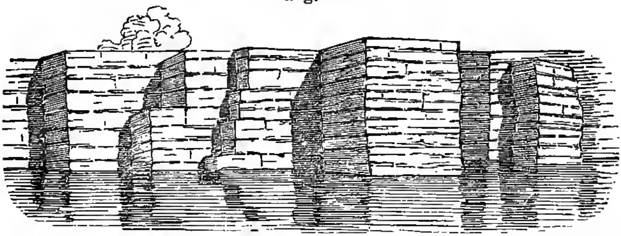
Thus it is seen that the water courses, rivers, and creeks have been of great service to geologists in laying open and displaying the rocks. It was mostly by the careful study of such sections that the formations of Tennessee were made out.

181. Horizontal Position of Layers or Strata.—The figure on the last page represents the outcropping edges of *horizontal* or *level* strata. The sketch on this page is a good picture of such strata. The stratified rocks have this position over very large areas of North and South America and the other continents of the globe. The rocks of more than two-thirds of Tennessee vary but little (with few local exceptions) from a horizontal position. The part

of the State thus having horizontal rocks commences with the western half of the Cumberland Table-land, and extends to the Mississippi river, which includes all of Middle and West Tennessee.

182. In addition to the horizontal position, the sketch shows what is meant by *jointed structure.* It is not uncommon to find the rocks of a region thus divided into very regular angular

Fig. 9.



blocks by cracks which run down to great depths. The cracks are called *joints.* These joints are often a great help in the quarrying of rocks.

183. Extent of Strata.—In connection with the horizontal position, it will be well to notice the horizontal *extent* of the strata, or how they spread out laterally. These sheets of rock, in some cases, extend short distances; in others many, and even hundreds of miles.

184. As an example of their great extent, the *Black* or *Chattanooga shale* may be given, one of our best-known formations, and one which has often been mistaken as an indication of coal, or even for coal itself. This formation, which, for the most part, is a single stratum of blackish, bituminous shale (usually called slate), not at any point in Tennessee much over 100 feet in thickness, is found in the western part of the State outcropping along the hills on both sides of the Tennessee river. Going eastward,

it appears again all around the slopes of the Central Basin; thence spreads under the Cumberland Table-land; reappears at the eastern slope of this division, outcropping along its base, from Georgia to Virginia. It thus reaches, though comparatively so thin, for more than 200 miles through the State, always having the same relative position, so far as the formations above and below it are concerned. But this is not all; this Black shale reaches beyond Tennessee, extending in a northerly direction to the lakes and in a southerly far into Alabama. It may be seen at Blount Springs, in the latter State, presenting the same appearance that it does in Middle and East Tennessee.

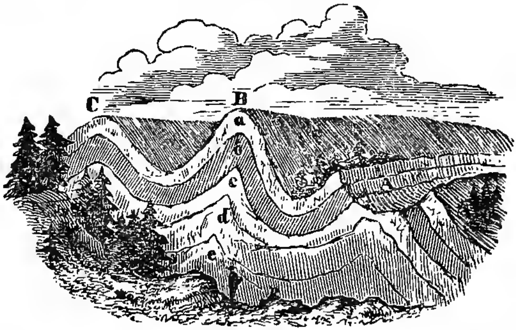
185. Original Position of Strata.—All the strata of Tennessee were once horizontal, or near horizontal. The strata, as stated before, were, at first, beds of sand, clay, and mud in the ocean. The materials of these, derived, during very long periods, from various sources, were by the action of currents and the waves spread out in layers over the nearly level bottom. Hence the horizontal position of the strata.

186. Folded and Inclined Strata; Formation of Mountain Ranges.—After the strata were formed, they were raised, *very slowly* and in great and wide masses, out of the ocean to make the continents. Over large areas they retain mostly their horizontal position, but over other areas they early began (in consequence of great *lateral pressure*) to *wrinkle* in a succession of immense folds, which in many cases ended in the upturning of the rocks and in the formation of mountain ranges. By this action the strata were crowded together, often broken, made to overlap, and *to dip* or be inclined at all angles. Such wrinkling or folding of the rocks has happened at different periods in the history of the world, the mountains resulting being of different ages. The Appalachian belt of mountains and valleys originated in a system of

folds completed in one of these periods; the coast range of California, in a system belonging to another and later period.

187. Lateral Pressure; Illustrated in an Apple.—The folds of the strata may be compared, in some respects, to the wrinkles on a drying apple. As the pulp of the apple dries it contracts, while the rind or skin does not. Thus the rind becomes too large for the pulp and as it does not separate from the pulp it is drawn or pressed together laterally until its superabundant part rises in wrinkles. The earth, like the apple, has two parts: a *crust*, and an inside part which is contracting. In one case the con-

Fig. 10.



traction is due to drying; in the other, to cooling from a heated condition, but the effects of contraction in the two cases are in some degree analogous. The outer cool and hard crust of the earth does not contract, and hence becomes too large for the heated and cooling interior. Its mass, like the parts of an arch, press laterally together until finally the crust relieves itself by forming one or more folds along some weak and yielding portion. Owing, perhaps, to the presence of melted, and hence fluid or plastic, rock below, the strata generally begin the folding by a downward movement.

188. The layers of rock, although appearing so stiff and inflexible, will, under certain conditions, bend to a considerable extent. Like piles of thick cloth, if pressed together from oppo-

site sides (lateral pressure) they will arrange themselves in folds (*plaits* we have called them).

189. Sections of Folds.—*Anticlines and Synclines.* The cut, Fig. 10, taken from Lyell's "Elementary Geology," illustrates well how strata may be folded, and how mountains may result. It was intended to illustrate the structure of the Swiss Jura mountains, but it illustrates as well the structure of some of the Appalachian mountains and valleys of Tennessee.

The letters a, b, c, d, and e represent strata or formations which, by lateral pressure, have been crowded into the folds A, B, and C. Both B and C are unbroken and *undenuded,* forming long, straight, mountain ridges. A, however, has been fractured and denuded along its summit, a trough or valley resulting along the line of elevation.

Sequatchee Valley, in this State, has much the same structure as the trough A. It also has been washed out along the back of a fold.

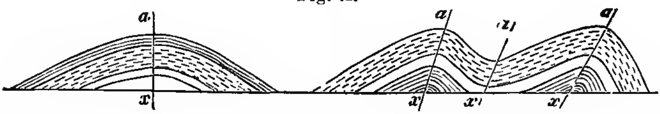
190. Fig. 11 represents the folding of the strata in one part of the Appalachian belt, as observed in Virginia. The groups of rocks are indicated respectively by the Roman numerals. Al-

Fig. 11.

though the folds are not complete, the student will be able, doubtless, to trace them out.

The names applied to the different parts of a fold are explained in Fig. 12.

Fig. 12.



191. An imaginary plane dividing a fold lengthwise and indicated by *a x*, is the *axis* of the fold. It is an *anticlinal axis* when the strata slope away from the plane in opposite directions, like the two sides of a roof.

The strata of an *anticlinal ridge* slope in this way. It is a *synclinal axis* when the strata slope *toward* the plane from opposite directions, like the sides of a trough or the letter V. In Fig. 12 *a′ x′* is a *synclinal axis* and the valley under *a′* is a *synclinal valley.*

Folds, like those above, that have had their tops removed (denuded) are sometimes called *decapitated* folds. In the annexed Figs. 13 and 14 if the fold *a* has its top removed, it becomes like *b*. The removal of the top leaves the strata dipping in one direction, and arranged in the order represented by the figures 1, 2, 3, 3, 2, 1. This order will be referred to again in speaking of the dips of East Tennessee rocks.

Fig. 13.

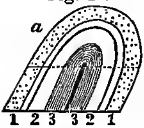
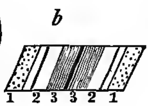


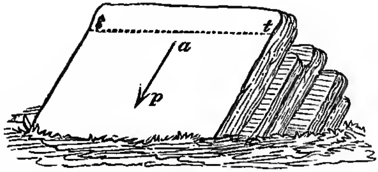
Fig. 14.



The left part of Fig. 11 shows a decapitated fold. The strata have been so removed as to form a valley along the back of the fold; and this valley is *anticlinal* in character, since the strata slope away from the *axis*. On each side of the valley is a ridge. The relations of the strata at the bottom and on the opposite sides of the valley, the way in which they outcrop and dip, are clearly presented.

192. Outcrop, Dip, and Strike.—These are words often heard from the lips of a geologist, and they are very important ones in his vocabulary. The first two we have already used a number of times.

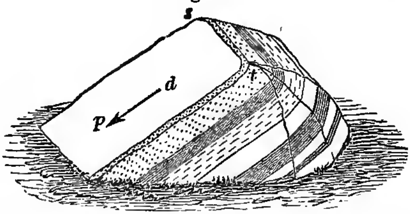
Fig. 15.



A rock *outcrops* when it projects out of the ground, or is otherwise exposed to view at the surface. An *outcrop* is the part thus exposed. The parts of the strata exposed in the cuts on this page are outcrops.

193. *Dip* is the degree of inclination below a horizontal position. Rocks may dip but little, in which case they are nearly horizontal; or they may dip a great deal, or may even stand upright on their edges, when they are said to be *vertical.* They may also dip in any direction, to the *north* or *south, northwest* or *southeast.* The most prevalent dip in East Tennessee is *to the southeast.* In Fig. 15 the dip is in the direction *a p,* and in Fig. 16 in the direction *d p,* as indicated by the arrows.

Fig. 16.



194. The strike is in the direction of the line along which an outcropping layer cuts a level surface. It is horizontal, and at right angles with the dip. In Fig. 16 the direction of the edge *s t* is the strike of the layers represented. In Fig. 15 *s t,* parallel with the upper edge, is the strike of the rocks shown.

195. Folded and Inclined Rocks in Tennessee.—The rocks of West and Middle Tennesse, as before stated, are mostly horizontal. Traveling in an easterly direction across the Cumberland Table-land, the strata continue horizontal until a point about halfway across is reached, when indications of the folding of the rocks are met with. The strata begin to be inclined or to *dip;* soon a great and complete fold is encountered, and, as the eastern edge of the table-land appears in sight, the western slope of another.

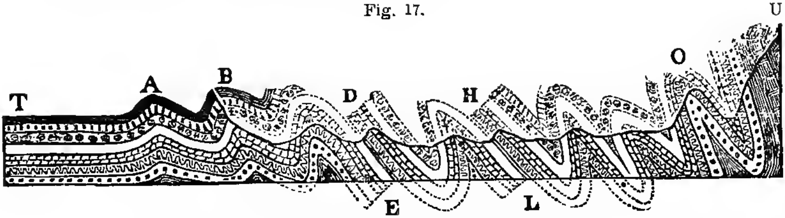
196. Entering the Valley of East Tennessee, the evidences of folding become more marked. The *rocks very*

generally dip to the southeast, and the edges of the strata are crossed in such succession as to show that the whole Valley was once entirely filled with a series of complete or half-made folds, much crowded together. The folds, by a lateral pressure immensely great, were raised and *pushed over* toward the northwest, the Table-land acting as a resisting line or bulwark.

In the Unaka Range the folding and displacement of the rocks is even more marked than in the Valley.

197. Fig. 17 will illustrate what has been stated. It is a section, from the southeast to the northwest, across the Valley of East Tennessee, or rather a section across East Tennessee, as it includes the Unaka Range on the right and the eastern part of the Cumberland table-land on the left. The section is partly ideal and partly true to nature. Its object is to show how the strata have been wrinkled or folded in this part of the State. This it does, in a general way, satisfactorily. The form of the folds, the fact that they have been pushed over to the northwest against the Table-land, causing the strata for the most part to dip to the southeast, are, with other characters to be mentioned, illustrated by the cut. In constructing it, however, many details have been left out and some features exaggerated. The actual strata do not dip, as a general thing, so steeply, and some of the folds are less compressed.

Fig. 17.



Illustrative section across East Tennessee.

198. It will be observed that the folds are divided *by a curving and wavy line,* which commences at B and terminates at U, into two parts—a light-shaded and a dark-shaded part. This line represents the *actual surface* of the Valley of East Tennessee, and of the slopes of the mountains on each side. The portions of the folds above this line have been *denuded,* or worn and washed away. They once filled what is now the Valley with mountain masses of rocks; but by vast erosion or wear, continued through a long time and mainly by the agency of water, they have been removed and their strata worn down to the present surface. This explains why the edges of the strata outcrop on the surface.

199. Displacements or Faults.—The rocks in their efforts, under pressure, to form folds have not always succeeded in doing so. A series of strata would break and one edge of the series would *slide over* the other, making one overlap the other and producing a displacement of the rocks, called a *fault.* In some cases the strata have been much crushed, and the rocks thrown into complicated positions. In Fig. 17 the part between D and E shows a displacement or fault. The edge D was once joined to E; but the series of strata was broken across and the edge D was pressed up and over E. Between H and L is a similar displacement or fault.

200. The plane of separation between the overlapping part D and the overlapped part E is the plane of the fault. This, on the actual surface of the country (the section which is indicated in the figure by the wavy line, as stated) appears as a line running generally in the same direction with the outcropping edges of the strata. When a geologist travels across such a line or fault, he at once observes that the proper sequence or order in which the strata naturally follow each other is interrupted. After passing the fault, the very series over which he has been traveling will begin again. Thus, if he has traveled over the edge of strata designated by a, b, c, d, and e, and then comes to a fault, he will, after passing it, meet perhaps with b again, and then with c, d, e, etc., in order as before. Indicating the fault by a vertical

line, the arrangement may be a, b, c, d, e | a, b, c, d, e, or something similar, the series on each side of the fault being more or less complete.

201. There are many long *faults* or displacements in East Tennessee, along which two sets of strata, one of which was once, when the rocks were undisturbed and horizontal, hundreds, or it may be thousands, of feet above the other, are brought right together. These faults extend, like the ridges and valleys, in a northeasterly and southwesterly direction.

202. It may be stated here that the order in which the strata of a denuded or decapitated fold are arranged is well illustrated in Figs. 13 and 14. Traveling across the edges exposed as at b, the order is 1, 2, 3; 3, 2, 1. In this case 3 was the lowest stratum and 1 the uppermost, before the folding took place, or when the rocks were horizontal. If a fold lies *below* the surface, the order is reversed. Had the same strata been folded downward, the order would have been 3, 2, 1; 1, 2, 3, the uppermost stratum in this case being inside.

In the section Fig. 11, on page 74, the strata rise in an anticlinal fold on the left, and sink in a synclinal one on the right. The order in which they outcrop at the surfaee is, commencing at the left end, VI, V, IV, III; III, IV, V, VI; V; VI, V, IV, III, II.

203. (b) The Unstratified Form.—Unstratified rocks do not lie in layers or strata. As but few rocks having this form exist in Tennessee, we need not dwell here. On page 64 the unstratified condition is mentioned as a characteristic of *granite.* The rocks of trap dikes like the Palisades on the Hudson are also unstratified.

204. (c) The Vein Form.—This, in the classification on page 68, is given as the third and last form in which rocks occur.

Veins are made by the filling up of cracks or fissures in the rocks, the fillings being the veins. The fissures may have been very narrow, or many feet, or even rods, wide, the veins resulting being correspondingly thin or thick. They may have had also great depths. The materials filling the fissures may be quartz, calcite, or other minerals, often with the ores of metals.

In Fig. 18 two veins are represented, *a* and *b*. In Fig. 19 are

Fig. 18.

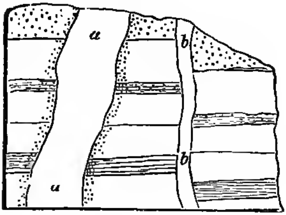
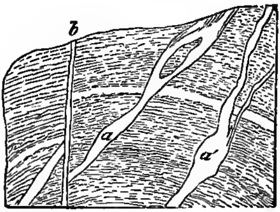


Fig. 19.



two irregular veins, *a* and *a'*. In this, moreover, is a third vein, b, which has been formed in a fissure made by the fracturing of the rocks, after the formation of the vein *a*. It is improper to call a *bed* of coal a vein.

205. There are hundreds of thin veins intersecting the limestone rocks of Tennessee. The material composing them is generally cystalline and white *calcite*. Some of them consist, in addition, of *fluor spar* and *lead and zinc ores* in small quantities. In the rocks of the Unaka Range are also many veins, the material of which is often white *quartz*.

The noted copper veins of Ducktown will be spoken of in Part IV.

The rock material and ores of most veins have been brought into the fissures through the agency of water. Dikes are veins formed by the filling of the fissures with melted rock.

II. Denudation.

206. Erosion and Removal of the Rocks.—The wearing and washing away, or, as geologists express it, the *denudation* (den-u-da'tion) of strata, have been referred to on previous pages. The rocks show the effects of such wear and removal on a stupendous scale. By the folding and consequent upturnings of the strata the rocks in mountainous regions often reached to elevations hundreds of feet above the level at which we now find them. All this elevated matter has been worn away by the action of rain, frost, and ice, and carried back to the sea. Contractions of the earth's crust raised the strata; water has cut them down and *sculptured* them into the mountains and valleys as we now find them.

207. Examples.—The elevation and subsequent denudation of the strata in East Tennessee have been explained on pages 77 and 78. There is good reason for believing that the strata which outcrop around and beneath the city of Knoxville once extended to elevations many hundreds of feet above the present surface. All that was above has been removed, and the city stands on the outcropping edges of the remnants of strata.

The rocks upon which Chattanooga and all the towns of the Valley of East Tennessee are built are outcropping remnants and have a similar history.

208. Horizontal rocks have also been subjected, in many regions, to great denudation. The gorges of the Colorado, spoken of on page 70, and, in Tennessee, the gulfs and cover of the western sides of the Cumberland Table-land, the whole of the Central Basin, the valleys of the rivers in Middle and West Tennessee, have been washed out of strata once continuous. At one

time the rocks exposed at Nashville had piled upon them a series of strata certainly not less than a thousand feet in height, and the same is true of all the towns in the Basin.

209. Formation of Sequatchee Valley.—This valley, the surface features and relations of which are described on this page, is a good example of the denudation of a great fold of the rocks. The structure of the valley is, as stated, much like the trough A in the cut on page 73. A fold was first formed, like B or C, and then the valley was excavated along its back.

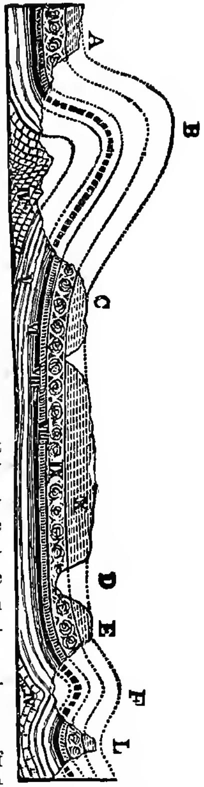
The cut on the opposite page, Fig. 20, is a section of the formations and country extending from a point north of Jasper, in Marion County, in a southeasterly direction, to the eastern base of Lookout Mountain, a distance not far from twenty miles. It begins at the point A on the *Cumberland Table-land* and crosses, in succession, *Sequatchee Valley* (A to C), *Walden's Ridge* (C to E), *Lookout Valley* (E to L), and *Lookout Mountain* (L). The dotted lines represent the portions of the strata that have been denuded. The lines under B present a cross section of the strata of the great fold and mountain (originally much like B in Fig. 10, page 73), the washing away of which, lengthwise along its summit, formed Sequatchee Valley.

210. This fold was raised out of the very bosom of the Table-land and to an elevation more than a thousand feet (at some points more than two thousand feet) above its top. It lay like a straightened and half-buried monster serpent, lengthwise with the Table-land, extending in a southwesterly and northeasterly direction for 225 miles, half in Tennessee and half in Alabama. The greater and southern part of the Tennessee half has been excavated, and is now Sequatchee Valley. The northern part, but partly denuded, is a broken range of mountains lying in a line with the valley and between its head and Emery river in Morgan county. Crab Orchard mountain is one of this range.

This Sequatchee fold, as we may call it, is the "great and complete fold" referred to on page 76, and is the first encountered in crossing the Table-land from the west.

211. We must add here that in Fig. 20 the fold B is represented in cross section, as if unbroken. This presents a simpler illustration. The real fold, however, is broken for much of its length. Generally there is a great break and displacement, or in other words a great fault, running lengthwise along its western base. Fig. 21 is a cross section, at a point of the valley, showing the fold and also the fault. F F is the line of the fault. It is seen that the formations are greatly raised on the right hand (southeasterly) side; so much so that the lower part of formation IV is brought up and made to abut against the upper part of formation V.

Fig. 20.



In many parts of the Sequatchee range much greater displacements than this are met with, some of them bringing formation IV up against formation IX or X. In these latter cases, all formations below IX and X are completely buried. For this reason, a number of formations well seen on the east side of Sequatchee Valley are wholly missing on the west side—buried out of sight. Displacements of as much as 5,000 feet occur.

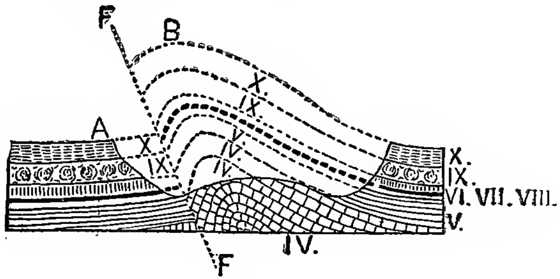
The fold B in Fig. 20 would be more typical if showing a fault and displacements similar to the fold in 21.

It is *to be noted* that the vertical scale of the sections in cuts 20 and 21—and for that matter, in most of the other cuts—is purposely greatly exaggerated over the horizontal scale. This fact ought to be kept in mind and due allowance made.

212. Valley-making and Ridge-making Rocks. Appalachian Geology.—We have seen how the rocks have been folded and elevated, and how then they have been denuded, or worn and washed, down to the valleys and

mountains, as we now find them. In this wear and denudation, the softer and the more soluble strata, such as *soft shales* and *limestones*, have yielded more to the denuding agencies, and have worn deeper, than the harder strata, as *sandstones, roofing slates*, and *gneissoid* rocks. The soft strata have thus been removed, while the others, resisting the wear, have, to a great extent,

Fig. 21.



remained. The excavation of the first has produced the valleys, and hence they may be called *valley-making* rocks; the others have been left, and form the ridges and mountains, and hence they are *ridge* or *mountain making*. The distinction is a good one, and will aid us in understanding the surface features, the *sculpturing* and topography of the country.

213. In Fig. 11 (page 74), on the left-hand side a denuded fold is represented, the strata of which are numbered II, III, IV, V, etc. No. III is soft, and has, by yielding to denudation, produced a valley. No. IV is a sandstone, separated into an upper and lower part by an interposed layer. This rock is hard, has not yielded like the others, and hence remains in high ridges on each side of the valley.

214. We can now understand why it is that the valleys and

ridges of East Tennessee, and in fact of the whole Appalachian belt from Maine to Alabama, about which we have said so much, run in parallel lines to the northeast and southwest. First, the rocks were raised in a succession of immense folds, lying in the characteristic direction; then they were worn and sculptured by denuding agencies, the soft strata of the folds yielding and forming valleys, the hard in good part remaining and making ridges and mountains. The outcrops of the strata, and hence of course the valleys and ridges, have the direction of the original folds.

215. Denudation of Horizontal Strata.— In the denudation of *horizontal* strata, hard rocks, as sandstones, have often resisted wear so as to form table-lands. The Cumberland Table-land owes its formation and preservation, as a table-land, to the hard sandstones which form its top or cap (page 20). Without this *protecting* rock, the limestone strata which make the base of the mountain would have long since been removed. The out-standing cliff-edges of the Table-land are due to the weather and water resisting power of the rock.

216. The outlines of the Central Basin are sharply defined by the hard, often flinty, edges of the rocks which cap the Highland Rim. These edges, as well as the cliff-edges of the Table-land, are like the edge of a stiff crust capping some soft material.

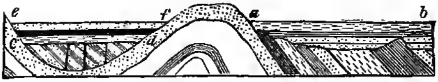
Hard layers very frequently give origin to ledges and terraces on the sides of hills. The ledges C and B in Fig. 8, page 69, have been formed by such layers.

217. Unconformable Strata.—It has often happened in the geological revolutions of the earth that one set of strata has been folded or tilted, and that afterwards the surface thus formed has been again submerged, and another set of strata deposited upon it. In such a case the strata of the two sets are said to be *unconformable.* They do not *conform* in position. Those of the first or lower set are tilted, while those of the second or upper

are horizontal, and rest upon the edges of the first. The strata of the first are also plainly the older.

218. We may have, in this way, three or more sets unconformable to each other. In Fig. 22 there are three sets of unconformable strata. Those of the lower and older set are folded on the left side of the cut, and dipping and denuded on the right; those of the second rest in a hollow of the first below the

Fig. 22.



line *c d;* while those of the third set, lying on both sides of the fold, are horizontal, and rest upon the rocks of the other two. The horizontal strata in this cut may be of two different ages—that is, two sets instead of one—for the part under *e f* may have been deposited before, or after, the part under *a b.*

CHAPTER X.

Fossils and Classification of Animals.

III. Fossils.

219. Remains of Animals and Plants in the Rocks.—The rocks, especially limestones, sandstones, and shales, often contain, imbedded in them, shells, corals, bones, teeth, leaves, stems, and other remains or relics of animals and plants. Some rocks are entirely made up of them.

220. Most of the rocks about Nashville, for example, are little else than *consolidated masses of shells and corals*, the remains of animals that formerly lived and flourished. The very dust of the streets "was once alive."

The shells and corals are different in kind from those now met with in the seas of the world. Many of them have strange forms. Their home was the great ocean which in past ages covered Tennessee. This ocean teemed with living beings, and, as individuals were constantly dying, its bottom became covered deeply with accumulations of shells and coral skeletons, whole or broken, and mixed with mud. The accumulations were in time consolidated, afterwards raised out of the sea, and are now our limestone rocks. Such is the history of most, if not all, the limestones of the State.

221. What Fossils Are.—These relics of animals and plants, of whatever kind, are called *fossils* by geologists. The word *fossil* is from a Latin word meaning "that which is dug up," and as fossils are dug out of rocks, or obtained from crumbling rocks, the name is sufficiently appropriate. Fossils are often called *petrifactions*, and many of them are petrified. When a piece of wood or a shell has its matter *replaced* by flint, or any other substance different from wood or the original matter of the shell, it is *petrified*. Fossils, however, are often found which are but little changed.

222. The Uses of Fossils.—Every formation has, to a great extent, its own kind, or species, of fossils. Most of those found in one do not occur in any other.

The species of fossils found in the rocks about Nashville or Knoxville are quite different from those found around McMinnville, for the reason that the two places are on very different formations. On the other hand, the fossils found at Lebanon are the same as those occurring at Shelbyville, the formation of the two places being the same.

223. In this is seen one of the important and practical uses to

which these relics may be put. A person well acquainted with the fossils of any particular formation can tell, at localities it may be very distant, whether the rocks he meets with belong to such formation or not. A geologist traveling for the first time in a country can often know, *simply from the shells in a layer of limestone*, that the rocks of the region belong to the coal formation, and that beds of coal may be found; or that they belong to some other formation, in which a search for coal would be useless. The fossils give the information. Further, by means of fossils the formations of Tennessee can be identified with formations in the State of New York, in Canada, or even in Europe. Were there no such means of easy identification, the strata extending from Tennessee to New York might often be followed or traced out; but to follow or trace out strata from Tennessee to Europe would be impossible.

224. The study of the fossils, a branch of science called *Paleontology* (pa-le-on-tol′o-gy), a word meaning "the science of ancient life," has supplied the means of uniting all the formations in one grand and continuous record, or *history*. Indeed, without these remains geology would lose very much of its interest and importance. Of this, however, we shall learn in the next Part.

225. The Animal Kingdom: Its Classes, Etc.—To have any proper or practical knowledge of fossils, it is necessary for the student to know something definite about the characteristics and classification of animals and plants. Let us consider the animals first.

226. The various and countless species of animals that now live, or have lived, upon the earth are first divided into two great groups—namely, the *vertebrates*, or those having an internal backbone, or internal jointed

skeleton; and the *invertebrates*, or those without a backbone. This division is a convenient one for geological purposes.

227. The *vertebrates* constitute a subkingdom by themselves; the *invertebrates* are divided into nine *subkingdoms.* Thus there are ten subkingdoms in all, and these are still further divided and subdivided. Below a condensed table of the leading divisions, with examples and brief descriptions, is given. The table begins with animals of the simplest or lowest organization, and ends with those of the highest grade, of which the *quadrupeds* and *man* (the highest of all) are examples. This order places the *invertebrates* first. This is the most natural and corresponds nearly with the order in which the animals, as represented by their fossil remains, occur in the formations. The first and lowest of the formations contain the remains of invertebrates only. Ascending through the series, we next meet with the remains of fishes, the lowest class and the first of *vertebrates* to appear; and then, in succession, with *reptiles*, *birds*, and *mammals.* Of the mammals, the quadrupeds belong to the latest and uppermost formations. Man's place is at the very top.

A. Invertebrates.

1. *Protozoans.*—This name means "first animals." The subkingdom includes animals of the simplest organization. The division of them known as *rhizopods* is of most interest to the geologist. (See further, page 91.)

2. *Sponges.*

3. *Cœlenterates.*—The name is composed of words meaning "hollow intestine," and refers to the fact that the animals, usually very small, are sack-like and the whole inner lining has digestive power. They have a mouth which is usually surrounded by

radiating tentacles, so that in some cases they resemble expanded flowers. These are the animals that secrete the stony corals of our seas and that have originated the fossil corals of the rocks. (See further, pages 91 and 92.)

4. *Echinoderms.*—Many of the animals included here have their skins covered with spines, hence the name *echinoderms.* There are three classes of geological importance: crinoids, star-fishes, and echinoids or sea urchins. (See pages 91 and 92.)

5. *Bryozoans.*—Sea mosses. These animals are very small and secrete delicate, stony corals resembling lace work. (See pages 93 and 94.)

6. *Brachiopods.*—Lamp shells. The brachiopods are protected by shells of two pieces or valves. They have been confounded with clams and muscles, but in the latter the two valves are *right* and *left* and applied to the sides of the animal; while in the brachiopods the valves are *top* and *bottom* valves, one being applied to the back of the animal and the other to the central side. (See page 93.)

7. *Mollusks.*—Animals having soft bodies which are generally protected by an outside shell, as *snails, periwinkles, muscles, clams, oysters, cuttlefish.* The last have an internal bone or shell. The word *mollusk* is from the Latin *molluscus,* meaning "soft." (See page 94.)

8. *Vermes or Worms.*—(See page 95.)

9. *Arthropods.*—The word means "jointed feet" or "jointed limbs." They are animals with the skin more or less hardened into a *crust,* which is divided across into rings or segments jointed together and forms an *outside* skeleton. The *insects, centipeds* (hundred-legged worms), *spiders, lobsters,* and *crawfish* belong here. The forms of some of them are shown on page 96.

B. Vertebrates.

10. *Vertebrates.*—Backboned and many of them familiar animals. The following five classes are given:

(*a*) *Fishes.*—Animals breathing by means of *gills.* The following are divisions: *Common fishes* like the *perch, trout, salmon; ganoids,* as the *sturgeon* and *gar-pike;* and *selachians,* including the *sharks* and *rays.*

(*b*) *Amphibians.*—Toads, frogs, and salamanders are examples of this class. They breathe by gills when young and by lungs when older.

(*c*) *Reptiles.*—Cold-blooded, with a covering of scales or a naked skin. Alligators, lizards, turtles, and snakes.

(*d*) *Birds.*—Well-known animals with a covering of feathers.

(*e*) *Mammals.*—Animals that suckle their young and have a skin provided with hair on the whole or some part of the body, as the *dog*, *horse*, and *all quadrupeds*, *seals*, *whales*, etc. *Man* is included here.

NOTES AND ILLUSTRATIONS.

228. Rhizopods (rhiz′o-pods) were inclosed in shells (consisting of one or more *minute cells*), and these, though generally not larger than grains of sand, were so abundant as to form the greater part of some rocks. Chalk is largely made of them. *Rhizopod* means "root-footed." Some of these animals extended out fiber-like or thread-like arms through pores in their shells; hence the name.

229. Cœlenterates and Echinoderms.—The animals now included in these two subkingdoms were once known as *radiates*. Among them we have the *coral-making* animals or the *polyps; starfishes; crinoids* or the *stone lilies;* and *sea urchins*, called *echinoids* (ech′i-noids.)

The cœlenterates and echinoderms are of great importance to the geologist. Many of them have *hard* parts, either an inside unjointed skeleton called *coral*, or a sort of hollow shell or box, made up of stony pieces, and covered with a kind of skin. Most of the kinds are abundant in the seas of the present day. Multitudes lived in former times, and their remains fill many of the rocks.

In the group on the next page (Fig. 23) 7, 8, and 9 are pieces of polyp-masses. The flower-like ends are the living polyps, each with a circle of tentacles around the margin, and a mouth in the center. When the animals die, the stony coral, which supported them, remains, and is often a beautiful structure.

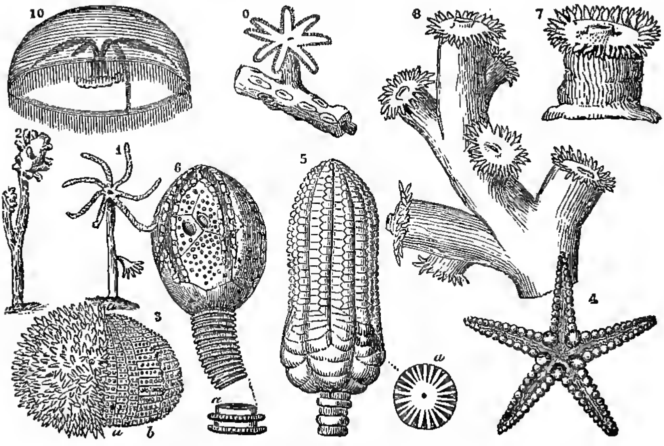
At the upper left-hand corner 10 is an umbrella-shaped *jellyfish;* below this, 1 and 2, are others resembling polyps. Some of the kinds form corals.

At 4, in the lower right-hand corner, is seen a *starfish*, an animal related to the crinoids next described, but having no *stem*.

230. Numbers 5 and 6 are *crinoids* (cri′noids) or stone lilies. *Crinoid* means *lily-like*. These animals have been compared to flowers, either with the petals expanded, star-like, or closed in the bud. They are fixed to the bottom of the sea by a stem which makes them all the more like flowers. It is only, however, in their forms that they happen to be something like flowers; in structure

they are altogether different. The crinoids consist of a hollow body or box, made up of stony pieces, which contains the digestive organs. The mouth is at the upper part of the box. Many of them have arms, also made of pieces, which they can spread out or close up, as a flower does its petals. In 5 the arms are closed up. Number 6 is a crinoid which had no arms. It shows the body and a part of the stem. The stems by which they are supported, and at the same time attached to the bottom, are often a foot or more in length, and can be bent, like a backbone, in any direction at will. They are made up of stony buttons piled one upon another, and held together by small muscles. 5 *a* is one of the buttons magnified; 6 *a* represents two of the buttons of this specimen. When the animal dies the stems often fall to pieces, the buttons becoming separate.

Fig. 23.



1, 2, 7, 8, 9 cœlenterates; 3, 4, 5, 6, echinoderms.

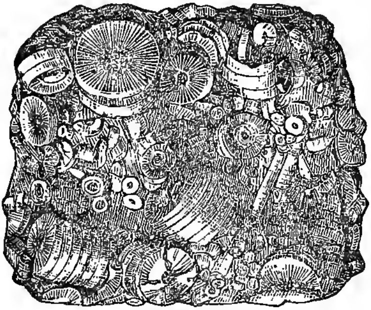
On pages 132 and 147 other species of crinoids are figured.

Crinoids were very abundant in the ancient seas. Many of the rocks of Tennessee contain their remains. The buttons of the stems especially are very common. Some limestones are in great part, or wholly, made up of them, hence they are known as *crinoidal limestones.* Fig. 24 represents a piece of such limestone. It is seen to be made up of broken stems and separate buttons of different sizes. The buttons vary in size from that of a nickel

down to little disks, which, when put together, would form a stem no larger than a knitting needle.

In Fig. 23, on the last page, 3 is one of the forms of a sea urchin. Its outer part is a hollow box made up of pieces and covered with spines. In the cut the spines on one side are removed to show the box. The mouth of this animal was below, at or near the center.

Fig. 24.



231. Bryozoans.—The word means "moss-animals." They are of minute size, and pack their little shells together in thin layers, lace-like or branching forms. The layers often incrust larger shells, the hard parts of other animals, stones, etc. Some of the more delicate kinds resemble moss, and hence the name. The aggregation of shells may be called corals, and the animals themselves look like polyps. Fig. 25, 2 is a magnified representation of some of them standing out of their cells. On the right 2*a* is a section of one still more magnified.

232. Brachiopods.—As stated, these animals have shells in two pieces or valves which are *top* and *bottom*, and not as a muscle, *right* and *left*. The name *brachiopod* (brach′i-o-pod) means "arm-foot" and refers to the fact that the animal has two spiral arms within. Generally the valves in muscles are *vertical* when in position, and alike in form and size, excepting that one is right and the other left. They are symmetrical like the lids of a book. On the other hand, the valves of brachiopods are unlike in form and size, are horizontal like a chest and its lid, and are unsymmetrical.

No. 10 in Fig. 25 is a brachiopod. The larger valve (the ventral) has a beak with a hole in it, through which a cord passes, by which the animal is attached to a rock or some sup-

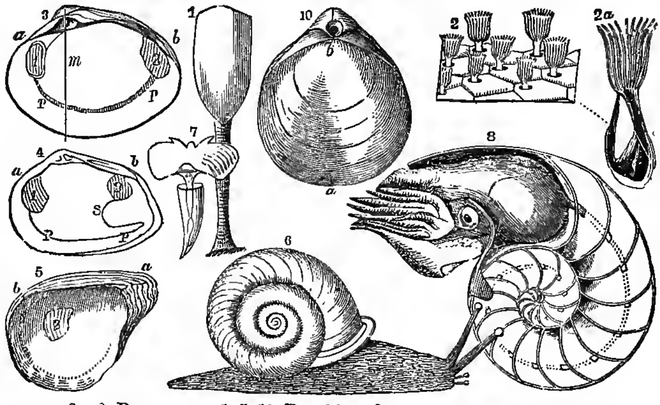
port. No. 1 is another, a species of the genus *Lingula*, the long cord of which is shown. See also pages 129, 133, and 135.

The fossil shells of brachiopods are very abundant in the older formations.

233. Mollusks.—The mollusks include the following divisions:

(*a*) *Those having arms around the head*, and possessing large eyes. They are called cephalopods (ceph′a-lo-pods), a term derived from two Greek words meaning "head and foot." In the group on this page (Fig. 25), 8 is one of them, the *Nautilus*, and a living species. The animal is seen occupying the large end of a coiled shell, which has had one side removed to show the interior. It will be seen further that the shell is *divided into chambers* by cross partitions. Most of the extinct

Fig. 25.



2*a*, 2, Bryozoans; 1, 7, 10, Brachiopods; 3, 4, 5, 6, 7, 8, Mollusks.

cephalopods had chambered shells, which are often found fossil. The shells were not always coiled; some were but slightly curved; many even straight. The latter belong to the genus *Orthoceras* (or-thoc′e-ras), a word meaning "straight horn." In the group (Fig. 31) on page 121, 6 is an orthoceras. They varied in length from an inch or two to six or more feet. The shells of the cephalopods had a tube, called the *siphuncle*, running through the chambers; that of the nautilus is indicated in 8. All of the cephalopods having external chambered shells, with the single exception of the nautilus, are extinct.

(*b*) *Mollusks,* like the snail, *having a head, but no arms,* and generally carrying a spiral shell. Many of them are called *gastropods* (gas′tro-pods), from the fact that they make a sort of foot of the under side of the body. The common *snail* (6 in Fig. 25), *periwinkles* from the rivers, and *sea snails,* which supply many beautiful and large shells, are examples. Others are called *pteropods* (pronounced ter′o-pods) a word meaning "wing-footed," for the reason that they have a pair of wings for swimming. No. 7, in the group shown, is one of them.

(*c*) *Mollusks without heads,* called *acephals* (ac′e-phals). *Acephal* means "headless." The *muscles, clams,* and *oysters* belong here. The shell of one of these animals consist of two pieces, or valves, applied respeetively to the right and left *sides* of the body. In Fig. 25, 3, 4, and 5 are valves of acephals. The margin *a* of 3 and 4 is the front, the mouth facing this; the margin *b* is the back. No. 5 is the valve of an oyster. The acephals are also known as lamellibranchs.

234. Worms.—The surface of rocks often show markings which appear to be tracks made by worms on the mud or clay before it hardened into rock. Some sandstones contain *rods* that appear to have been formed by the filling of borings made by worms in the sand before hardening.

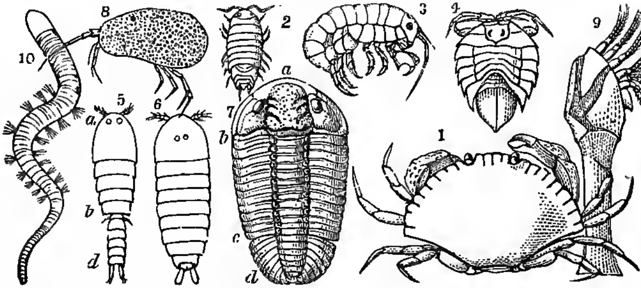
235. Arthropods.—These animals are divided into *land arthropods,* including *insects, spiders,* and *centipeds;* and *water arthropods,* as *crabs, lobsters, crawfish, shrimps.* Of the water kinds, 5 and 6 (Fig. 26) are representations (magnified six times) of the female and male of a species having feet or legs comparatively defective.

Near the middle of the group, 7 is a *trilobite* (tri′lo-bite) resembling in some respects 2 and 4. *Trilobites* are known only by their fossil remains, as none are now living. They form an order of arthropods of great importance to geologists. The word *trilobite* (tri-lobed) refers to the division of the back of the animal lengthwise into three lobes or ridges, more or less marked. They were of all lengths, from half an inch, or less, to twelve inehes. In the trilobite represented, the end *a* is the *head piece,* the end *d* the *tail piece,* and the middle part *b c* the *body,* which was divided into movable segments. Some of the trilobites had the power of doubling themselves up. On page 114 is a good figure of another species; and in the group on page 115 and on page 123 other species are represented.

Nos. 2, 3, and 4 (Fig. 26) are bug-like water arthropods. No. 4 has the form of a trilobite.

236. The animal represented at 8 belongs to a group of arthropods called *ostracoids*. They are inclosed in a two-valved shell, like the *oyster*, and hence the name. But the shell is thin and otherwise quite different from that of the oyster. Many of them are minute animals, and swarm in some waters. Fossil ostracoids, looking like good-sized black beans, are common in

Fig. 26.



the rocks of Shelbyville, Lebanon, the lower parts of Columbia, and of other points where the same strata are exposed.

No. 9 of the group is a *barnacle*, an arthropod which attaches itself to rocks, wood, ship bottoms, etc., by a fleshy stem. No. 1 represents a *crab*. On the left of the group, 10 is a marine worm, known as the *lug-worm*.

237. Vertebrates.—The classes of this subkingdom have been given in the table on pages 90 and 91. We shall add only a few paragraphs and cuts with reference to the *sclachians* and *ganoids* among the fishes.

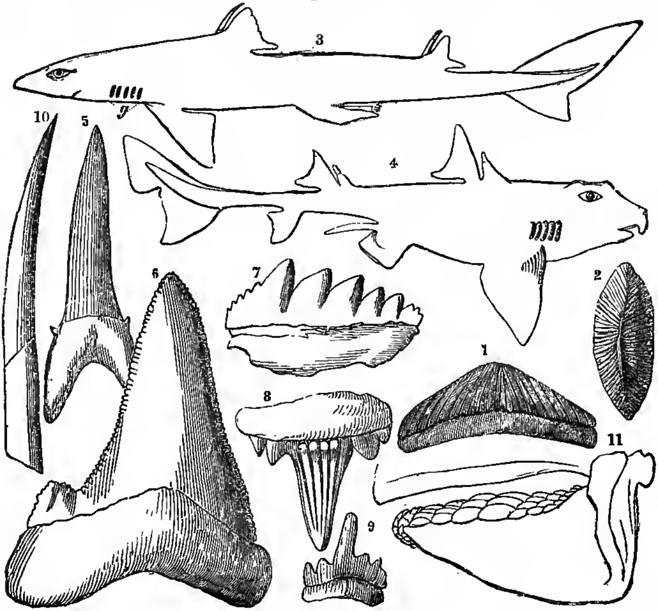
238. The *selachians*, including, as stated, the *sharks* and *rays*, have a skin covered with hard, bony, and rough points. Their skeletons are in good part cartilage in place of bone. The term *selachian* is from the Greek for *cartilage*.

In the group of cuts (Fig. 27) 3 and 4 are outlines of sharks. The two differ in the position of the mouth and also in the arrangement of the teeth. In the latter the teeth are in pavements on the jaws. No. 11 shows them on the lower jaw.

All the remaining forms of Fig. 27 are illustrations of different kinds of sharks' teeth. These fishes came in with the ganoids, at an early date. Their teeth are often found fossil.

239. The *ganoids* (ga-noids) are represented, comparatively, by but few living species. The order is an ancient one. Fig. 28

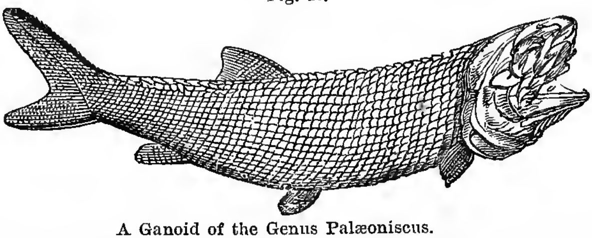
Fig. 27.



Sharks and Sharks' Teeth.

is one of these fishes as found in the rocks. The tail in the oldest division of ganoids is *vertebrated*—that is, the backbone, or

Fig. 28.



A Ganoid of the Genus Palæoniscus.

cartilagenous part representing it, extends out to the extremity of the tail, generally to the point of the upper lobe, as in the figure,

but sometimes to the point between the lobes. In some more modern ganoids, as well as in common fishes, the backbone stops at the root, or commencement, of the tail. Ganoids were covered like gar-pikes, with thick, bony, and shining scales, or rather plates, quite different from the thin, flexible scales of common fishes. The *shining* plates have given name to the order, the term *ganoid* coming from a Greek word which means "shining."

240. The Plant Kingdom.—The plants of the earth, including both living and fossil forms, are divided into two great groups —namely:

(*a*) *Flowerless plants* or *cryptogams* (cryp′to-gams) as *ferns, seaweeds, mosses.* They have no proper flower, nor true seeds, there being in the place of the latter simple *cells,* which botanists call *spores.*

(*b*) *Flowering plants* or *phenogams* (phen′o-gams) as most of the common plants, *oaks, pines,* all our forest and fruit trees. most weeds, *grasses,* garden herbs, and shrubs. They have distinct flowers and true seeds.

The following notices will be sufficient for our purposes:

A. Flowerless Plants.

1. *Thallogens,* (thal′-lo-gens) *bed* or *mass-growers.* Humble plants of lowest organization; made up wholly of cellular (pithy) tissue, which may be soft or compact and hard, watery, or dry and crusty; growing without any distinction of stem, leaf, or root, in flat expansions, layers, strings, branching tubes, ribbon forms, masses of symmetrical or irregular shape or in single cells. *Seaweeds, lichens,* and *fungi* (pronounced fun′ji) are *thallogens.* The fungi include *mushrooms, toadstools, puffballs,* the minute plants which form *mold, mildew, smut,* and *rust.* The dry, crusty expansions that grow on rails, logs, and rocks are *lichens* (lich′ens.)

2. *Anogens* or *top-growers.* Wholly of cellular tissue, like the last, but growing up in *leafy stems.* The mosses belong here.

3. *Acrogens,* also *top-growers,* the word *anogen* (an′o-gen) having the same meaning. These are plants containing woody tissue and tubes or ducts such as found in plants of higher grade. Among them are *ferns, lycopods,* or *ground pines,* and *equiseta* (eq-ui-se′ta) the latter known as *horsetails* and *scouring rushes.* Species of all these divisions, some of them large trees, occur in the rocks as fossils, especially in the strata of the coal formation.

B. Flowering Plants.

4. *Endogens* (en′do-gens) or *inside growers.* The class includes the *palms*, *cane*, *rattan*, *grasses*, *Indian corn*, *lily.* The plants have no proper bark; the wood of such as are trees or shrubs does not grow by the successive addition of new layers to the outside; hence the end of a palm log or rattan stick shows no rings of growth.

Remains of palms occur in the later formations. Palms are numerous now, and may be regarded as modern plants.

5. *Exogens* (ex′o-gens) or *outside growers.* Including *oaks*, *maples*, *apple*, *pine*, *spruce*, and all our forest and fruit trees, and most shrubs and herbs. They have a bark, and show rings of growth.

There are two orders of exogens. The first embraces the *gymnosperms* (gym′no-sperms) or *naked-seeded plants*, the seeds lying naked at the base of the scales of cones. The *pines*, *spruces*, *hemlocks*, etc., called *conifers* (con′i-fers) or *cone-bearing* trees, belong to this order. The *cycads* are also included. These are trees usually with short trunks, having the appearance of palms, uncoiling their leaves after the manner of ferns but yet in their wood and cone fruits like the pines. There are but few cycads living. In the age following the coal period they were abundant and were the characteristic trees of the forests. The conifers appeared long before the coal age, and have constituted an important part of all succeeding forests to the present day.

The *second* embraces the angiosperms (an′gi-o-sperms) or *covered-seeded plants.* The seeds are inclosed in seed vessels. All the exogens, except the conifers and cycads, are included in this division.

The angiosperms, as magnolias, willows, walnuts, maples, oaks, poplars, etc., first appeared, with the palms, in the later formations.

IV. The Geological Theory of the Earth.

241. The Fiery Earth.—The earth was once a ball of fire, like the sun and the fixed stars—a globe, perhaps, of liquid rock. As a consequence, it has ever been a cooling body. This, at least, is the theory of geologists, and they have good reasons for entertaining it. Even now an auger could not anywhere penetrate its com-

paratively cooled exterior a few thousand feet without reaching heated rocks.

242. The water from the deepest artesian wells—wells made by boring, and from which the water flows spontaneously like a fountain—is too warm for ordinary drinking. The deepest mines have a high temperature. The multitude of volcanoes, the melted rook ejected through fissures, and the formation of dikes (page 59) earthquakes, the phenomena of hot springs, the metamorphism of rocks (page 58), the folding and crumpling of strata (page 73) all point to the probable existence, at the present time, of fire-seas below, as well as to the liquid and fused condition of the entire earth in the unmeasured past.

243. The Crust.—It appears as if the original liquid globe, by slow cooling through very long time, began finally to form a crust. This was at first thin and fragile, and easily broken up by the fiery billows. It formed again, was broken and reformed again and again. At length, as the cooling proceeded, the crust become more stable, and the *first rocks* were made. These were crystalline and unstratified, perhaps chiefly granite.

In the meantime the surface cooled enough to permit the watery vapors, hitherto in some form a part of the atmospheric envelope, to condense and cover the earth. Thus the ocean appeared, which at once began the work of making *stratified rocks.* The waters, still hot, by wearing and denuding the first rocks, strewed the sand or mud resulting over the submerged exterior, covering and concealing the worn surfaces of the first granites, or whatever they were, with stratified layers.

244. Thus was the first set of strata formed, and, having been deposited and consolidated in hot waters, they

were doubtless crystalline. And these in turn, worn and washed by the waves, supplied new sand and mud for new layers, beneath which they too were more or less buried. And this continued until thousands of feet of strata were in some places piled up.

245. Land and Life.—While this was going on the continents and the ocean beds began to be outlined; limited areas of the rocks rose above the waters, and the dry land appeared; the heat was diminished, and plants, soon to be followed by animals, were seen—the first introduction of life by the great Creator. This marks an epoch—a distinct day. Now began the making of the fossiliferous or fossil-bearing rocks, which continued through long ages.

246. Note.—As a sequel to what has been said, let the reader add the account of the "Origin of Tennessee Rocks" (p. 56), the starting point of which dates from this time; also, and more especially, the paragraphs on pages 76 and 77 bearing on the *position*, *folding*, and *elevation* of the strata, as well as the paragraphs under "Denudation," commencing on page 85, which treat of the *erosion* and *wear* of strata, and of the *sculpturing* they have undergone in the production of the present surface.

247. The Central Mass of the Globe Not Liquid.—We have spoken of the cooling of a liquid globe, and the formation of a solid crust at its exterior. It must not be inferred from this that we believe the whole interior to be now in a melted, liquid state. It is probable, indeed, on account of the immense pressure existing, that solidification began first at the center.

The great mass of the earth within may be solid, though more or less heated, and between this inner

solid part and the crust may lie great fire-seas, or lakes of melted rock.

248. Thickness of the Crust.—The thickness of the supposed crust of the globe is not known. The estimates vary from 40 to 100 miles. In boring artesian wells (p. 100) the temperature of the rocks (after passing the limit to which the heat and cold of the seasons penetrate) increases at the rate of about 1 degree for every fifty or sixty feet of descent. At a depth of about 8,000 feet the rate of 1 degree for fifty feet would give heat enough to boil water, and at 28 miles heat sufficient to melt iron. But pressure has much to do with the melting of substances. A temperature sufficient to melt iron or rock at the surface would fail to do so at a considerable depth in the earth.

PART III.

THE FORMATIONS.

CHAPTER XI.

Classification of the Formations.

249. Past time is divided by geologists into eras, periods, and epochs. The eras are the largest divisions. Their subdivisions are periods, and the subdivisions of the latter are epochs. Often the word *age* is used, as, for example, *age of fishes* or the *age of reptiles*, denoting the period in which these animals, shown by their fossil remains, were especially prominent or characteristie.

These are *time divisions*. In speaking of the *divisions of the rocks* we use different terms. All the strata of an era, taken together, are known as a group, as, for example, *group* of strata of the Mesozoie era. So the strata of a period is known as a *system*, as the *system* of strata of the Devonian period.

250. Very commonly, however, the word *formation* is used in place of *group*, *system*, etc. We say, for example, the Mesozoic formation, or the Devonian formation. It would be better to confine this term (if used at all) to the minor divisions, as, for example, the Niagara formation, the Nashville formation, or the Black Shale formation. As a matter of convenience, however, we shall use the term in its broadest sense.

On pages 104 and 105 is a table of the geological formations or rock divisions of Tennessee. The numbers read from below upward. The arrangement is ascending in the order of age.

251. In the column under *epochs* we have, with two exceptions, the names of the individual or primary formations of the State. The exceptions are the "Ocoee" and the "Crystallines," at the bottom of the column of periods. These two divisions, especially the latter, are each a complex of many individual formations, which, as yet, have not been satisfactorily separated. We treat them here as temporary or provisional divisions.

TABLE OF THE GEOLOGICAL FORMATIONS OF TENNESSEE.

Eras.	Periods.	Epochs.
V. **Cenozoic.**	Recent. *Quaternary.*	36. Alluvium.
	Pleistocene. *Quaternary.*	35. Milan Loam. (Yellow Loam.) 34. Memphis Loess. (Bluff Loam.)
	Neocene. *Tertiary.*	33. Lafayette. (Orange Sand; Bluff Gravel.)
	Eocene. *Tertiary.*	32. La Grange. (Lignitic; Flatwoods; Bluff Lignite.) 31. Middleton. (Clayton; Porter's Creek.)
IV. **Mesozoic.**	Cretaceous.	30. Ripley. 29. McNairy Shell-bed. (Green Sand; Rotten Limestone.) 28. Coffee Sand. (Eutaw.)
III. **Palæozoic.**	Carboniferous.	27. 26. 25. B. Coal Measures. { Brushy Mountain Measures. Tracy City Measures. Bon Air Measures.
		24. 23. 22. 21. A. Mississippian or Subcarboniferous. { Mountain Limestone. St. Louis Limestone. Tullahoma Formation. Maury Green Shale; Ball or Kidney Phosphate.
	Devonian.	20. Black Shale. (Chattanooga Shale.) 19. Swan Creek Phosphate. 18. Hardin Sandstone. 17. Camden Chert. (Oriskany.)
	Upper Silurian (or Silurian).	16. Linden Limestone. (Lower Helderberg.) 15. Clifton Limestone. (Niagara.) 14. Rockwood Beds. (Clinton.) 13. White Oak Mountain Sandstone. 12. Clinch Mountain Sandstone. (Medina.) 11. Clinch Mountain Red Shale.

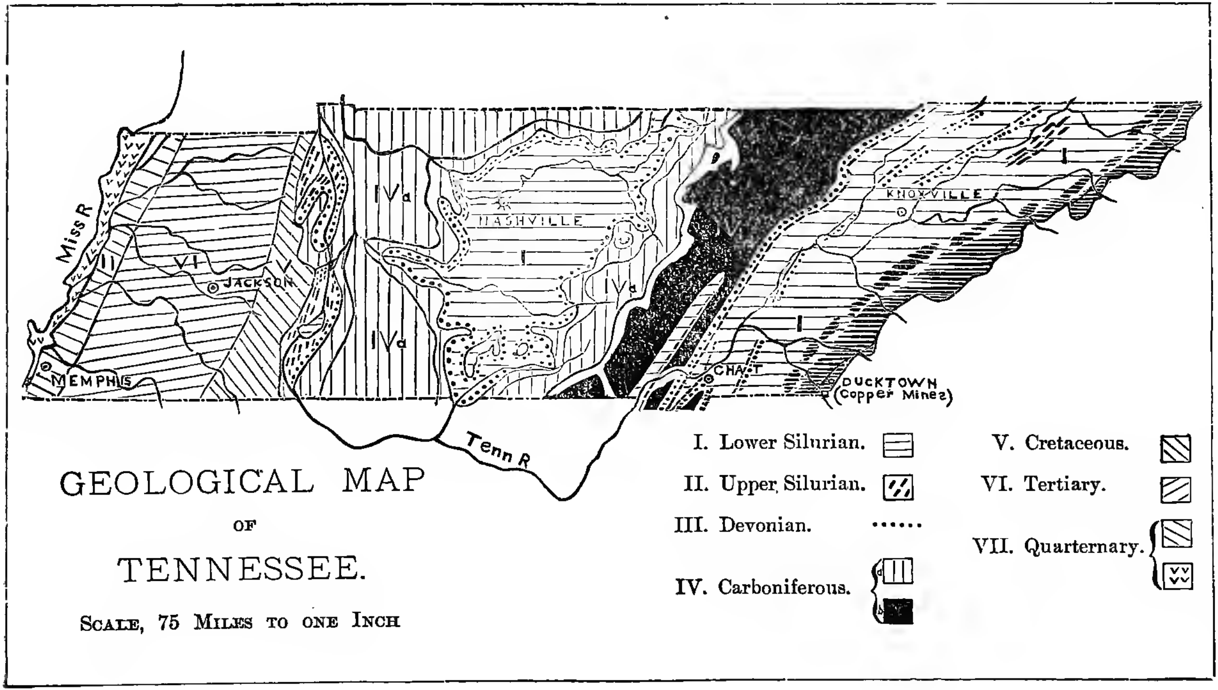
ERAS.	PERIODS.	EPOCHS.	
III. **Palæozoic.**	LOWER SILURIAN (OR ORDOVICIAN).	(*East Tennessee.*) 10. Sevier Shale. Includes the following interpolated beds or lenses: (*c*) Upper Red Marble. (*b*) Crinoid Bed. (*a*) "Iron" Limestone. 9. Knoxville Marble. 8. Lenoir Limestone.	(*Middle and West Tennessee.*) 10*a*. Hudson. (College Hill; Cincinnati.) Hudson Phosphate. 9*a*. Nashville. (Trenton.) (*g*) Stromatopora. (*f*) Cyrtodonta. (*e*) Ward. (*d*) Dove. (*c*) Capitol. Mt. Pleasant Phosphate. (*b*) Orthis. (*a*) Carter. (Black River.) 8*a*. Stone's River. (Chazy.) (*d*) Lebanon. (*c*) Ridley. (*b*) Pierce. (*a*) Murfreesboro. (Central.)
		7. Knox Dolomite (Upper Part).	
	CAMBRIAN.	6. Knox Dolomite (Lower Part). 5. Knox Shale. 4. Knox Sandstone. 3. Chilhowee Sandstone.	Coosa Shale; Montevallo Shale and Sandstone. (Weisner Sandstone.)
II. **Eozoic.**	(2) OCOEE. (Algonkian? Talladega.)	Partially Crystalline, Conglomerates and Slates.	
II. **Eozoic.** and I. **Azoic.**	(1) CRYSTALLINES.	Provisionally made to include: (*b*) Crystalline Ocoee, and (*a*) True Archæan.	Mica and other Metamorphic Schists. Gneisses, Granites, Syenites. Dikes of Igneous Rocks.

252. In the middle column the periods are larger divisions, and include, severally, one or more of the primary divisions, or, as some would have it, represent each a *system* of formations. The Cretaceous Period, for example, includes the three following formations: the *Coffee sand*, the *McNairy shell-bed*, and the *Ripley*.

253. The eras in the left-hand column are the largest divisions, and each includes one or more periods. The names of the eras are from the Greek. *Azoic* means "no life," and the rocks included under the name show no fossil remains, and are supposed to have been formed very early in the history of the earth, before the introduction of plants and animals. *Eozoic* means "dawn of life," and refers to a time of long duration when organic beings began to appear, and includes rocks which contain the first fossil remains. *Palæozoic* means "ancient life." It was a time during which animals and plants of a type more or less ancient abounded. The rocks included are rich in fossils. *Mesozoic* means "middle life," and refers to the fact that the life of the time was intermediate in character between the ancient and the modern. *Cenozoic* is "recent life," and means life of existing types, such as we see represented in living plants and animals.

254. A Geological Map and Section.—Before beginning the descriptions of the formations of the State, we introduce here a small map of Tennessee, showing the areas of outcrops of the rocks of the several periods represented. With the exceptions noted below, the names of the periods are given and the areas of outcrops are indicated by different shadings. The exceptions are three of the oldest divisions of the geological series, as follows: *Crystallines*, the *Ocoee*, and the *Chilhowee sandstone*. These are "mountain formations," their rocks making the great mountains in the *extreme eastern part* of the State. They are taken together and are represented on the map by the heavier horizontal shading.

255. The rest of the map explains itself. It is seen that there are two great areas of *Lower Silurian* rocks; other great areas of the *Carboniferous*, one of them the

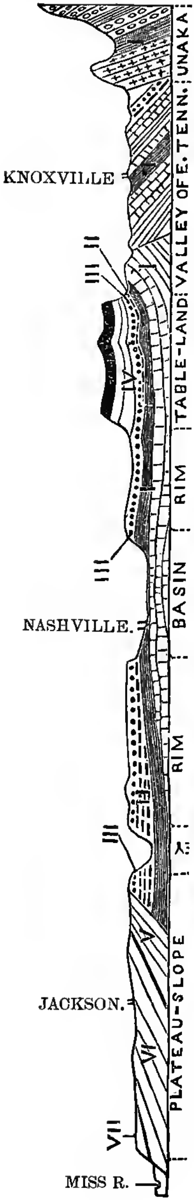


GEOLOGICAL MAP

OF

TENNESSEE.

SCALE, 75 MILES TO ONE INCH



A Geological Section through Tennessee from North Carolina to the Mississippi River.

black area, which represents the Tennessee coal field; and others again of the *Cretaceous*, *Tertiary*, and *Quaternary*. The *Upper Silurian* is mostly seen in lines of outcrops, though there is a considerable area of it in the valley of the Tennessee river west of the meridian of Nashville. The Devonian is represented by lines of dots seen chiefly in Middle and West Tennessee.

256. It will be instructive to compare this map with that on page 8: It will be seen that there is a correspondence in the areas of the two. The former indicates, in a general way, the geological formations of the natural divisions which the map on page 107 shows.

The section on this page goes with the sketch map. It extends from the North Carolina line, through Knoxville, Nashville, and Jackson, to the Mississippi river, and will serve to show the relative position, dip, and manner of outcrop of the strata.

257. In the description below the order of the table on pages 104 and 105 will be followed.

The reader will recall that the first three divisions, the *Crystallines*, the *Ocoee*, and the *Chilhowee sandstone* constitute a group of *mountain* divisions. They are so called for the reason that their rocks enter into the composition and structure of the great Unaka ridges so prominent along the extreme eastern border of the State.

THE FORMATIONS.

I. AND II. AZOIC AND EOZOIC ERAS.

1. CRYSTALLINES.

258. The rocks of this division are fully crystalline. It may be considered that the body of them lies in North Carolina and that the areas in Tennessee are but portions cut off by windings or offsets in the line dividing the two States.

259. The rocks are mostly mountain-making; occur in four detached areas, or stretches, in the mountain region along the North Carolina line. The first area, the longest and greatest, lies in Johnson, Carter, and Unicoi counties. The Roan of Carter, and the Big Bald of Unicoi, are famous mountains of the area. The second area is a part of the southeastern side of Cocke county; the third, a southeastern projection of Munroe; and the fourth, the southeastern corner of Polk.

260. The division of "Crystallines" includes:

First, the Azoic of geologists; and

Secondly, such beds above the Azoic as have been thoroughly metamorphosed and made crystalline. They are placed here provisionally and as a matter of con-

venience, the separation of the crystalline Ocoee from the Azoic not having yet been satisfactorily made.

261. The *Azoic* is a great series of unseparated formations of unknown thickness. They are the oldest rocks known, and are chiefly schists, granites, and allied rocks, all highly crystalline. Cutting these vertically, or at high angles, are many dikes of igneous rocks. These rocks and dikes are well seen in the famous Roan mountain of Carter county.

262. The second division of the Crystallines are mostly rocks of a later age, the *Ocoee*, that have been made fully crystalline by thermal and other dynamic agencies. They are chiefly gneisses and schists. Some dikes of igneous rocks are met with.

263. Taking the Crystallines *as a whole*, the following may be said of their economic products: Desirable granites and gneisses might be quarried in all the counties; the epidote granite (unakite) of Cocke is a notable example. Many of the igneous rocks could supply useful and handsome material, as for example, a noted porphyritic one of Carter. Millstones were formerly quarried. The group yields iron ore in all the counties; notably, magnetite and hematite in Carter, limonites and turgites in Polk. Gold is found at a number of points. The copper ores of Polk county are well known. Many other less important minerals occur, the copper mines of Polk supplying a great variety.

The soils as a rule are thin; the tops of the ridges are often more or less void of trees, prairie-like, and affording good grazing ground.

II. EOZOIC ERA.

2. Ocoee.

264. The rocks of the Ocoee are imperfectly crystalline, and have an estimated thickness of 10,000 feet. They are a great series of alternating conglomerates and slates, well seen along the grand rapids of the Ocoee river in Polk county. The group contains locally beds of limestone and limestone conglomerate. Its rocks are preëminently mountain-making. The chief rocks of the great belt lie in Polk, McMinn, Monroe, Blount, Sevier, and Cocke and next west of the Crystallines; the rocks also are seen in the eastern mountain ranges of Greene, Washington, Unicoi, Carter, and Johnson. Among the great mountains of the Unaka chain, the Big Butt in Greene, the great Smoky in Sevier, the Balds in Monroe, and the Big Frog in Polk are formed of Ocoee strata. Approximately, the group occupies 1,300 square miles of the State's surface.

265. Its rocks supply building material, roofing slates, conglomerate and breccia marbles, paving and road materials; they are the gold-bearing strata of the State, as seen in McMinn, Monroe, Blount, and Cocke; supply also iron ores; galena, some of it argentiferous; heavy spar, and pyrites. Important discoveries are to be looked for in this series of formations.

Soils thin with occasionally richer areas. Lands nearly all wild and forest-covered. Small mountain farms are encountered at rare intervals.

266. The following subdivisions of the Ocoee have been proposed:

(*a*) *Wilhite Slate.* Lowest. Dark blue or black slate, contains limestone lenses, limestone conglomerate, also sandstones and quartz conglomerate. Thickness, 300 to 800 feet.

(*b*) *Citico Conglomerate.* Massive conglomerate with sandstone and sandy shale. 500 to 1,100 feet or more.

(*c*) *Pigeon Slate.* Resembles the Wilhite slate. Thickness, 1,300 to 1,700 feet.

(*d*) *Cades Conglomerate.* Thick beds of slate, sandstone, and conglomerate. Prominent in the mountains about Cades Cove. Possible thickness, 2,400 feet.

(*e*) *Thunderhead Conglomerate and Slate.* Conglomerate of the Big Frog Mountain in Polk county, and of the Thunderhead and other mountains of the State line. Estimated thickness, 3,000 feet.

(*f*) *Hazel Slate.* Mainly black slate with some thin sandstones and conglomerates. Most of it in North Carolina. 700, estimated.

(*g*) *Clingman Conglomerate.* Occurs on Clingman Dome. Much like the Thunderhead conglomerate. 1,000 feet.

III. PALÆOZOIC ERA.

CAMBRIAN.

3. CHILHOWEE SANDSTONE.

267. The thickness of this formation is 2,000 to 3,500 feet; a mountain-making series. A heavy group of sandy shales, sandstones, and fine conglomerates; the sandstones often light-colored, sometimes quartzose; the shales darker and showing mica scales. The rocks are well seen in the Chilhowee Mountain, in Blount county.

268. This mountain or mountain ridge is a good type of numerous detached mountains, having the same general structure and form. These detached mountains lie lengthwise, end facing end, tandem fashion, in lines extending along the western foot of the great Unakas from Virginia to Georgia. The following are some of

them: Iron and Holston mountains of Johnson, Carter, and Sullivan; Buffalo and Cherokee mountains, of Unicoi and Washington; Meadow Creek mountain, of Greene and Cocke; English's mountain, of Cocke and Sevier; Chilhowee, the type mountain, of Blount; Guide mountain, of Monroe; Starr's, of McMinn; and Bean's, of Polk. The highest elevations range from 2,500 to 3,500 feet.

269. The strata yield superior building stones, flagstones, good road material, and heavy spar. Iron ores are found in quantity in deposits along the base of its mountains or in the foothills, and with the iron ore often manganese. These ore deposits pertain to the shales of the overlying formations.

The soils are thin, but often supply grazing grounds on the tops of the ridges.

270. The following subdivisions of the Chilhowee have been proposed. They commence with the lowest and ascend.

(*a*) *Sandsuck Shale and Starr Conglomerate.* The shale, dark bluish gray and sandy, containing mica scales, parts of it calcareous with beds of impure limestone.

(*b*) *Cochran Conglomerate.* Clean quartz sandstone passing into conglomerate. 1,500 feet.

(*c*) *Nichols Shale.* A micaceous sandy shale, blue when fresh, weathering to yellowish brown.

(*d*) *Nebo Sandstone.* A white quartzite or quartzose sandstone; caps the rocks of Starr's Mountain.

(*e*) *Murray Shale.* Sandy shale interbedded with thin saudstone. But little of this subdivision.

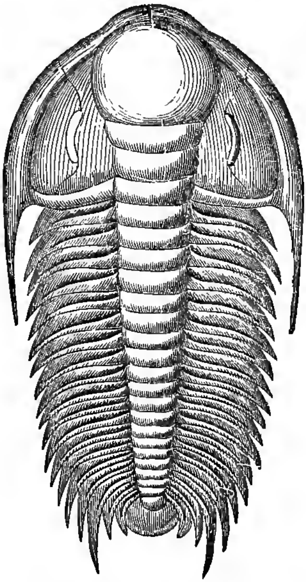
271. The *Knox group*, next above the Chilhowee sandstone, includes three formations in ascending order, as follows:

Knox Sandstone,
Knox Shale, and
Knox Dolomite.

The three severally correspond to as many types of topography in the great Valley of East Tennessee. Their rocks, with a single local exception, belong, with those of the Crystallines, Ocoee, and Chilhowee, to the eastern end of the State. The exception is an uplift of dolomite, fifty miles west of Nashville, in Stewart and Houston counties.

All are Cambrian, excepting the upper half (2,000 feet) of the Knox Dolomite, which is referred to the Lower Silurian.

4. Knox Sandstone.



A CAMBRIAN TRILOBITE.

The figure on this page represents one of the old-time animals. It belongs to a genus called *Paradoxides*, some of the largest of which were twenty inches long.

272. The characteristic rocks of this formation are hard shales and thin sandstones; beds of softer shale occur; rocks are of variegated colors, brown, red, green, buff, gray, etc. Interstratified are often heavier sandstones, calcareous beds and dolomites. Thickness, 1,000 feet and more. The surfaces of the rocks of the division often show fossil seaweeds in abundance.

Sharply crested, roof-like ridges are a characteristic topographical feature in regions where the strata are tilted. The following ridges are examples: Webb's, Beaver, Bull Run, and Pine, crossed successively in going from Knoxville to Clinton. These are but a few of them.

Many of the iron ore beds in the foot-hills of Chil-

howee and allied mountains rest upon the outcrops and are in the débris of this formation.

5. Knox Shale.

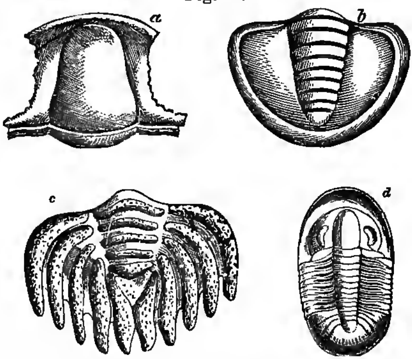
273. Variegated shales are characteristic rocks; colors often bright and pleasing. Interstratified more or less are thin layers of blue limestone, which is often oölitic. The shales are more calcareous to the northeast, and as a division not so well defined. Thickness, from 2,000 to 4,000 feet.

The formation is valley-making and of great interest in an agricultural way. The aggregate area of its lands are a large proportion of the arable and fertile part of East Tennessee.

Madisonville, Rutledge, and Rogersville are among the towns located in Knox shale valleys.

Fossil shells and trilobites are found in some of the layers of the Knox shale, especially in the limestone layers. The figure (29) on this page shows some of the forms of trilobites found in this formation.

Fig. 29.



The cut *a* is part of the head piece of one; *b* and *c* are tail pieces; *d* is an entire animal.

6. Knox Dolomite.

274. This, as a whole, is the most massive formation of calcareous strata in Tennessee. It is apparently divided, nearly half and half, between two great geological divisions, as follows:

6. *Knox Dolomite*, lower half, referred to the Cambrian.

7. *Knox Dolomite*, upper half, referred to Lower Silurian.

This subdivision is disregarded on this and the following page, the formation being described as a whole. In the Eastern Valley it is very conspicuous; the formation of many characteristic ridges; seen, too, in uplands and valleys. It is a great mass chiefly of sparry dolomite, with some limestone. The lower part is blue, and often oölitic and fossiliferous; upper part, gray, with blue layers; middle and upper part, more or less cherty, with occasionally heavy layers of chert. Thickness of the formation, not far from 4,000 feet.

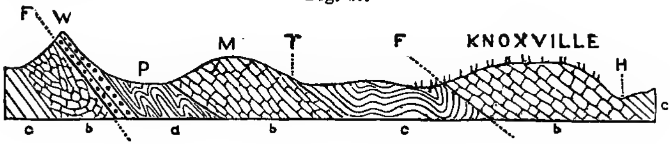
275. In regions of tilted strata a broad, rounded ridge is its chief topographical feature; the surface of the ridge is often covered with angular, light-colored, cherty gravel. Many long ridges belong here—as, for example, Black Oak, Copper, and Chestnut ridges, intersected in going west from Knoxville; Big Ridge, in Greene; the ridge Knoxville and Athens are in part built upon; and Missionary Ridge, east of Chattanooga. These are but a few of them.

276. The slopes of the Knox dolomite ridges often supply rich and desirable agricultural tracts. In regions of

horizontal strata their lands are very productive and held in high esteem.

The formation affords building material, a variety of marbles, rock for making lime, chert for roads, and a number of minerals and ores: limonites, hematites, magnetite, pyrites; lead ores, zinc ores, manganese ores, and heavy spar.

Fig. 30.



277. The section on this page (Fig. 30) illustrates the character of the rocks, and how they lie at Knoxville and for a few miles to the northwest of Knoxville. It commences at Webb's ridge (W), extends through the ridge M, and through Knoxville to the Holston river at H, a distance of about three miles. The strata (b) upon which the greater part of Knoxville rests belong to the Knox dolomite. It will be seen that they form a ridge. The oblique lines F and F are lines of faults, or displacements.

From F, on the left, to T the section shows the Knox group and its three divisions. The dotted bands under W represent layers of the Knox sandstone. These form the *sharp* Webb's ridge, one of the Knox sandstone ridges. Under P we have the Knox shale, outcropping in a valley (Poor Valley). Under M are the rocks of the Knox dolomite. From T to the right-hand F are rocks of higher formations—*Lenoir*, *Knoxville marble*, and *Sevier shale* (pp. 120–122).

The ridge M and the Knoxville ridge have the same formation. The first is sometimes called *Flint* ridge, on account of the abundance of loose chert upon it.

278. Some of the Knox dolomite ridges have been mentioned. Others are *Wallin's* ridge, in the eastern part of Claiborne coun-

ty, *Chestnut* and *Big* ridges (really parts of the same ridge), in Sullivan and Greene. There are several of the same kind between Cleveland and Benton, the latter place being situated on one of them. Benton, Maryville, and Dandridge are on the same Knox dolomite range or ridge. An ill-defined ridge of this class extends from Greenville to Newport, the former place being on its south-eastern side, and the latter on its northwestern. Another of like character reaches from Russellville to Virginia, running between Rogersville and the Holston.

Just west of Washington, in Rhea county, is a wide range of Knox dolomite, which runs parallel with the eastern base of the Cumberland Table-land. There is also a wide one in Campbell and Claiborne counties. West of Decatur is one which, in its northern extension, lies on the east side of Kingston.

The Knox dolomite is the formation of Blountville and Jonesboro, of Morristown, Mossy Creek, Newmarket, Loudon, and Charleston, and in part of Tazewell, Kingston, and Chattanooga. It outcrops extensively in Sequatchee Valley. Pikeville and Bridgeport are upon it.

279. The Wells Creek Basin.—The Knox group is only met with, as we have seen, in the Valley of East Tennessee, excepting, as stated, within the *Wells Creek Basin.* This curious and unique basin lies on the south side of the Cumberland river, in the eastern parts of Stewart and Houston counties. It has an oval form, and includes an area of six or seven square miles. Its existence is due to the uplifting of the strata in a high dome, the top of which has been worn and washed away. The uplifting of the strata and the subsequent washing or denudation have been sufficient to expose the upper part of the Knox dolomite.

280. It may be stated here, once for all, that in this basin the other formations outcrop in rings around the Knox dolomite, very much as the layers of an onion outcrop on a fresh surface made by cutting off a side. The Silurian strata and the Devonian Black shale make the floor of the basin, and these are inclosed in a circle, or hilly rim, of Carboniferous limestone.

The Carboniferous rocks outcropping along the Cumberland river, for several miles both above and below the Wells Creek Basin, are very much disturbed, and dip at various angles.

CHAPTER XII.

Lower Silurian Period.

281. By referring to the map on page 107, it is seen that the Lower Silurian rocks are greatly developed in both Middle and East Tennessee; very limitedly in West Tennessee. Their maximum aggregate thickness is about five thousand feet, or, in round numbers, about one mile.

The first subdivision is:

7. Knox Dolomite, Upper Part.

282. This has been included in the description of the Knox dolomite above. It is about 2,000 feet thick.

283. The Lower Silurian rocks above the Knox dolomite, when observed in order from east to west, present at first two divisions: one, the lower, of *limestone*, from 50 to 600 feet thick; and the other, the upper, of *shale*, having a maximum thickness of 2,000 feet. Passing to the west side of the Valley of East Tennessee, the shale is more and more calcareous until it also becomes limestone, the two making a single body of limestone. And such the group continues, in its westerly extensions under the Cumberland Table-land, into Middle and West Tennessee.

284. Owing to the nature of the subdivisions, respec-

tively, of the Lower Silurian in the two great sections of the State, it will be best to consider them, first, as found in East Tennessee; and, secondly, as found in Middle and West Tennessee.

1. EAST TENNESSEE.

285. In taking up the subdivisions of the periods in this part of the State, it will be well to recall the fact that the strata, as a rule, dip to the southeast, and therefore outcrop in long lines running northeasterly and southwesterly for miles, in some cases diagonally quite through the State. Hence it is that the formations in East Tennessee occur mostly in long belts or strips.

The subdivisions (best seen east of Knoxville) are as follows:

8. LENOIR LIMESTONE.

286. This name is given to a stratum of blue shaly limestone which lies next above the Knox dolomite. It is spoken of on the last page as a lower division of the Lower Silurian rocks—a "limestone from 50 to 600 feet thick." The formation is well exposed in a quarry at Lenoir's Station, on the East Tennessee and Georgia railroad, hence the name. In the northeastern part of the Valley, in Cocke, Greene, Washington, Carter, and Sullivan counties, it is much reduced in thickness, often to 100 feet. It also becomes more compact. In the western part—that is, the part of the Valley next to the Cumberland Table-land—it is not separated from overlying limestone by any well-marked characters.

287. In the northern part of Jefferson county, and in the vicinity of Bull's Gap, it is often knotty in structure, breaks up into small blocks, and abounds in fragments of trilobites.

The Lenoir limestone abounds in fossil shells, corals, and sponges. It contains especially a large sea snail (called *Maclurea magna*) which is flat on one side, and frequently four and five inches across. On account of the abundance of this fossil the formation has been called the *Maclurea limestone.*

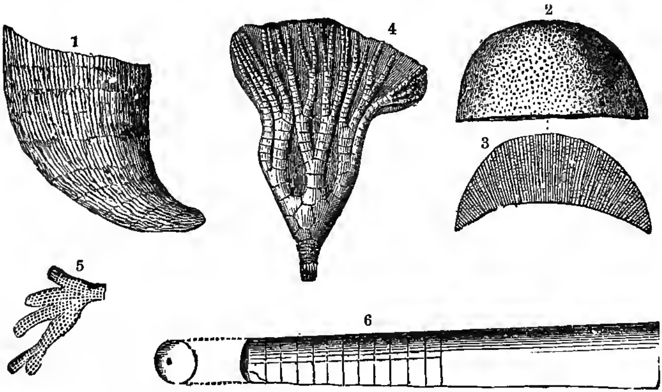
This limestone lies along the eastern base of the Knox dolomite ridge upon which Knoxville is built. The depot at *Strawberry Plains* is upon it, and it is seen, filled with the big sea snail, at *Kingsport*, in Sullivan county.

9. Knoxville Marble.

288. Red and gray marble. Three hundred and eighty feet thick. Worked at many points in East Tennessee.

It is a variegated, sparry marble, to a great extent made up of the fragments of fossil crinoids and corals. The belt of it runs lenthwise pretty well through the middle of the Valley of East Tennessee. It is found as high as Hawkins county, and as far south as McMinn and Bradley.

Fig. 31.



1, Streptelasma corniculum; 2, 3, Prasopora lycoperdon; 4, Taxocrinus elegans; 5, Stictopora acuta; 6, Orthoceras junceum.

The rocks of this group are well filled with fossils. These are mostly marine mollusks, corals, and trilobites. No remains of

fishes or land animals are found. Figs. 31 and 32 are representations of some of the fossil forms met with and characteristic of the group.

10. Sevier Shale.

289. Made to include the "Athens Shale." A great body of calcareous shales, weathering yellowish gray or buff; thin limestone, with hard, thin sandy layers occasionally present. This is the upper division of the Lower Silurian spoken of on page 119 as a "shale," with a maximum thickness of 2,000 feet. On the same page the gradual change of the formation into limestone as one goes westward is noted.

290. The hard, sandy layers give rise to peculiar conical hills, "Gray Knobs;" belts and areas of these are quite extensive, and make "knobby regions or belts." These are a marked feature in the southeastern half of the East Tennessee Valley.

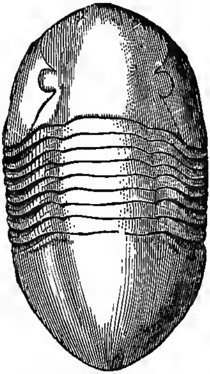
291. A remarkable belt of the kind commences at the Virginia line just above Kingsport, in Sullivan, and extends nearly to the Hiwassee river in McMinn county. It widens out around the Bays mountain group of ridges, covering parts of Sullivan, Greene, and Hawkins, and then reaches through parts of Jefferson, Cocke, Sevier, Blount, and Monroe to McMinn. *Sevierville* is within the belt, and *Newport* on the eastern edge of it. The knobby belts between Blountville and Holston mountain are also made of the shale.

The shale includes the following interpolated beds:

292. (a) "**Iron Limestone**" **Group.**—Consisting of layers of hard, ferruginous, sandy, fossiliferous limestone, dark-gray, bluish-gray, and iron-colored, weathering to a spongy, dark-brown, sandy mass. These are more

or less interlaminated with shales and thin sandstones. Maximum thickness, 700 feet.

Fig. 32.



Asaphus platycephalus.

The trilobite on this page is one of its fossils. The hard layers of the group give rise to lines of conspicuous "*Red Knobs*" running lengthwise with the valley.

A line of these is in sight across the river from Knoxville. It commences in the region of Strawberry Plains, extends through Knox County, the western parts of Blount and Monroe, through McMinn and Bradley, nearly or quite to the Georgia line. The principal line of red knobs has been referred to on a previous page.

293. (b) **Crinoid Bed.**—Shales and thin limestones noted for the crinoids and shells it has supplied. This bed outcrops just east of the Red Knobs in Knox county. Thickness, from 50 to 100 feet.

294. (c) **Upper Marble and Brown Shale.**—This interpolated bed is a stratum of *brown* or *brownish-red calcareous shale*, which becomes, at some points, variegated *marble* (the upper marble). The bed is seen in many valley ranges. It appears as marble in Knox County east of Knoxville, and as red shale west of that city. Some of this shale has been manufactured into hydraulic cement.

295. These interpolated beds have their greatest development in the central part of the Valley in Knox county, diminishing in volume, or running out, in a northeasterly and southwesterly direction. Outcropping

in belts, they soon disappear as one goes southeasterly or northwesterly.

296. The following section of the strata in the vicinity of Knoxville (best seen in going east from the city) will show the order and character of the beds mentioned:

(*a*) *Knox Dolomite.*—The rocks upon which Knoxville is chiefly built.

(*b*) *Lenoir Limestone.*—Blue argillaceous limestone, 500 feet.

(*c*) *Marble Beds.*—380 feet.

(*d*) *Sevier Shale.*—Its members in succession are as follows:

(1) *Calcareous bluish shale* mostly, but containing interlaminated layers of flaggy and iron limestone, 400 feet. The shale is buff or grayish in its weathered condition.

(2) *Iron Limestone,* weathering often to a porous dark-brown sandy material. Some of it affords flags for paving purposes. 250 feet. The iron limestone is highly fossiliferous.

(3) *Calcareous Shale,* with more or less flaggy fossiliferous bluish limestone, about 500 feet. The shale, like No. 1, is bluish, weathering buff or gray. The crinoid bed is at the top of this.

(4) *Red Marble* (*Upper Marble*).—Variegated, mostly red, 300 feet. As stated, this division is often brown or brownish-red shale.

(5) *Calcareous Shale* (the topmost portion). — Bluish shale, weathering like 3, containing flags of limestone. Thickness uncertain, owing to the folded condition of the layers. About 400 feet.

In the westerly part of the Valley the Lower Silurian rocks become throughout, as stated, chiefly limestone and have been named *Chickamauga Limestone.*

II. MIDDLE AND WEST TENNESSEE.

297. The lower strata of the Lower Silurian in Middle Tennessee make the floor of the Central Basin, while the higher outcrop pretty well up on the slopes of the hills, which all around make its sides. As a whole, the

rocks are limestones. Some beds of shales are met with, but are subordinate.

The divisions and subdivisions of the period are plainly given in the Table of Formations, on pages 104 and 105, which the student will do well to consult in connection with what is stated here. They are with their brief descriptions as follows:

8*a*. Stone's River.

298. This division represents a grouping of subordinate beds that is natural. They are met with in the valley of Stone's River, and are as follows:

299. (a) **Murfreesboro Limestone (Central Limestone).**—The lowest limestone of the Central Basin; light-blue, heavy-bedded, and often cherty; yields a red, warm, fertile soil (a cotton soil); 70 feet seen. Murfreesboro is near the center of a circular area of an outcrop of this formation. The area has a diameter of thirteen or fourteen miles.

300. (b) **Pierce Limestone.**—Seen at Pierce's Mill, on Stone's river north of Murfreesboro; mostly thin-bedded, bluish, fossiliferous limestone; 27 feet.

301. (c) **Ridley Limestone.** — Thick-bedded, light-blue limestone, 95 feet thick. The Pierce and Lebanon outcrop concentrically around the Murfreesboro limestone. The Ridley occurs also in Bedford and Marshall, and in the lowest rock of those counties; makes a good, fertile country.

302. (d) **Lebanon Limestone (Glade Limestone).** — Thin-bedded, very fossiliferous limestone; 120 feet. The towns of Lebanon, Shelbyville, Lewisburg, LaVergne,

and Fosterville are located on it. The two last towns are on opposite sides of Murfreesboro, and on the great concentric outcrop of the Lebanon formation, the outer one of the three outcrops that encircle the Murfreesboro limestone. Large areas of the formation are found in Rutherford, Bedford, Marshall, and Maury. The Lebanon is the characteristic formation of the old, red-cedar glades of Middle Tennessee. All the areas mentioned above were originally cedar glades. Soils fertile where not too rocky.

9*a*. NASHVILLE. (Trenton.)

303. This second division or epoch includes a higher series of limestones of the Central Basin. The different beds are well exposed and easily studied in and about Nashville.

304. (a) **Carter Limestone.**—This is the conspicuous light-colored limestone seen along Carter's creek, in Maury county. It is a light-blue, heavy-bedded limestone from 60 to 100 feet in thickness. It is seen in all of the counties of the Central Basin. Liberty in De Kalb, Statesville in Wilson, Woodbury in Cannon, and the lower part of Columbia in Maury are located upon it. Near Nashville it is seen in the lower part of the hills about Mt. Olivet and in the valley of Mill Creek. At a number of points it is quarried for building purposes and for burning with lime.

305. (b) **Orthis Bed.**—Bluish limestone, often siliceous or sandy. Sometimes in layers two or more inches in thickness, separated by shaly leaves. Weathers in places into yellowish sandstone and shale. Everywhere char-

acterized by containing or by being made up of the small shells or valves, often silicified, of a brachiopod known as *Orthis testudinaria.* To some extent a phosphate limestone. From 50 to 70 feet. Seen in sections at Nashville, Columbia, Franklin, and many other points; the lowest rock at Mt. Pleasant; has been made into hydraulic cement at Clifton, in Wayne county.

306. This rock by its outcrop guides to the horizon of the Mt. Pleasant phosphate deposits, for the latter rest immediately upon it.

The shell referred to is No. 8, one of the shells of Fig. 33, page 129. It is as represented here a little too small. It is often as large as a dime. A rock that *abounds* in the thin valves of this shell, or that is made up of them, may be set down at once as belonging to the Orthis Bed, for no other rock in the Central Basin is like it in this respect. Once recognized, the Mt. Pleasant phosphate may be looked for right above it.

307. (c) **Capitol Limestone, or Mt. Pleasant Phosphate.**—This supplied the rock for the building of the capitol at Nashville. It is a granular, current formed, laminated limestone of blue or light-blue color. In its structure thicker laminæ alternate with thin, darker laminæ, the latter richly phosphatic. A dressed block placed in natural quarry position exhibits on its vertical sides many darker lines, giving a banded or striped appearance to the surface.

308. Great interest attaches to the Capitol limestone, as it is the mother rock from which the extensive and valuable phosphate beds of the southern part of Maury

county around Mt. Pleasant, and the beds of a number of other counties in the Central Basin, have been derived. By long leaching under the soil, through the action of rain water and the acids of the decomposing organic matter, the limestone part of the rock has been removed and the less soluble phosphate part left. About Mt. Pleasant the rock was to begin with especially rich in phosphate.

309. The Capitol limestone sweeps in a great belt completely around the inner areas of the Central Basin. There is not a county in the Basin that may not show at least small areas of it, and hence no county that may not supply more or less of the Mt. Pleasant phosphate to the prospector.

Many of the best lands of the Central Basin owe their richness to the fact that their soils are derived from this phosphatic rock. See further, the part of this report on the Mt. Pleasant phosphate.

310. (d) Dove Limestone.—Chiefly dove-colored, compact bird's-eye structure, thick-bedded layers; thickness, 12 feet. The best building material of the series. Seen best in Davidson county.

311. (e) Ward Limestone.—Blue, coarsely crystalline, thick-bedded, fossiliferous limestone; quarried quite extensively, affording large slabs for paving. Thickness, 25 feet. Limestone more or less phosphatic.

312. (f) Cyrtodonta Bed.—Represented by two beds which do not occur together. They appear to replace each other. The first is a crystalline, ashen-gray, or flesh-colored limestone; in good part, a single stratum lying next above the Ward. Maximum thickness, 12 feet. It is mostly made up valves of a species of Cyrtodonta, a bivalve shell allied to clams. This gives name to the bed. The Nashville city prison is built upon the first-mentioned bed.

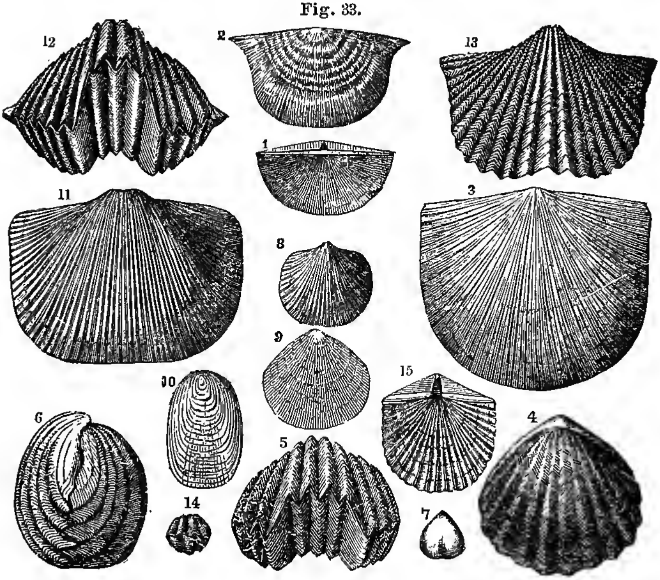
The second bed is dominated the Upper Dove or False Dove. Resembles the true dove (d) in having dove-colored, compact layers. Maximum thickness, 5 feet. These beds are most prominent in Davidson county.

313. (g) Stromatopora Bed ("Sponge Bed").—Within the corporate limits of Nashville, wherever the proper horizon occurs, is seen a rough stratum of blue, granular limestone, 2 to 4 feet thick, well packed with individuals of a huge so-called sponge named Stromatopora. Specimens are seen 2 feet in diameter, though usually smaller. The species is allied to the Hydrocorallinæ.

10*a*. Hudson, or Hudson Phosphate (College Hill).

314.—The uppermost of the Lower Silurian rocks in Middle Tennessee are referred to this division. It in-

Fig. 33.



Mollusks, and all *brachiopods*.—1, Leptæna sericea; 2, Strophomena (Leptæna) rugosa; 3, Strophomena alternata; 4, 5, 6, Rhynchonella capax; 7, 14, Rhynchonella (?) bisulcata; 8, Orthis testudinaria; 9, Obolus filosus; 10, Lingula quadrata; 11, Orthis occidentalis; 12, 13, Orthis lynx; 15, Orthis tricenaria. All the above are Lower Silurian fossils.

cludes a series of blue limestones with more or less shale, all abounding in fossils and from 50 to 150 feet in thickness. They are found at the tops of the hills about Nashville.

315. A most interesting feature is that the division in its upper part contains a phosphatic limestone from a foot to six feet in thickness, which by weathering or natural leaching, as in the case of the Mt. Pleasant rock, yields a valuable phosphate. Hundreds of tons of this phosphate have been mined in Davidson county. It has been mined, too, in Summer and Hickman counties.

316. This is the *second phosphate* in the geological series of Middle Tennessee, that of Mt. Pleasant being the *first.* The Hudson is about 160 feet above the Mt. Pleasant; that is to say, their respective levels are that far apart.

On the preceding page is a figure showing some of the fossils of the Lower Silurian. Large specimens of 3, 11, and 12 are found in the Hudson phosphate.

317. The Lower Silurian rocks of the State abound in economic products: the marbles of East Tennessee, wonderful for their extent and variety; marble also in Middle Tennessee; superior building stones, without limit; surprising deposits of rich phosphate rocks in Middle Tennessee; hydraulic limestones in all divisions; many minerals in all; among them iron ores, lead ores, zinc ores, heavy spar, gypsum, fluor spar, to which we may add finally natural gas and petroleum. Judging from the past, we may look at any time for fresh surprises in the discovery of valuable minerals and useful rocks.

No other series of rocks contribute such bodies of good lands; valleys and slopes in East Tennessee; valleys and plateau lands in Middle Tennessee, unexcelled in the State or out of it.

Upper Silurian Period.

318. As seen in the Table of Formations on pages 104 and 105, this period has six members or subdivisions, the whole hardly reaching an aggregate thickness of 2,000 feet. Its strata outcrops within comparatively small areas of the State. (See map, page 107.) In the Valley of East Tennessee four of its members, mostly sandstones, outcrop in long lines or belts, usually forming long, straight mountains and smaller ridges. Many of the ridges contain beds of red iron ore, which give them great interest. In the Central Basin the outcrops of the period are very limited, but in certain counties of the Western Valley, Wayne, Hardin, Perry and Decatur, one of the members, the Clifton limestone, appears over considerable areas.

On the eastern side of the Central Basin the Upper Silurian rocks are *wholly absent*, the Devonian resting directly on the Lower Silurian.

11. Clinch Red Shale.

319. Calcareous and sandy red shales. An East Tennessee formation. At some points 400 feet thick. Underlies the Clinch Sandstones (next mentioned) in Clinch, Bays, Powell's, Stone, Lone, House, and other mountains of the Valley. Found elsewhere appearing as if an upper member of the Sevier shale, or of its more westerly limestone counterpart.

12. Clinch Sandstones.

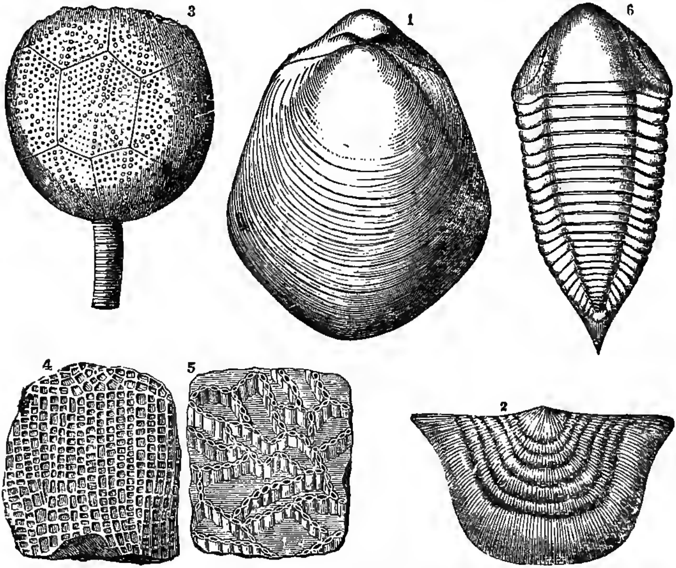
320. In East Tennessee. The hard cap or crest rock of Clinch and other mountains just named. A hard,

gray sandstone, very conspicuous in Clinch mountain, of which it forms the crest and southeastern slope.

13. White Oak Mountain Sandstone.

321. In East Tennessee. Sandstones of various colors with some shale, seen in White Oak mountains, in the

Fig. 34.



Crinoid.—3, Caryocrinus ornatus. *Corals.*—4, Favosites Niagarensis; 5, Halysites catenulata. *Brachiopods.*—1, Pentamerus oblongus; 2, Strophomena rhomboidalis. *Trilobite.*—6, Homalonotus delphinocephalus.

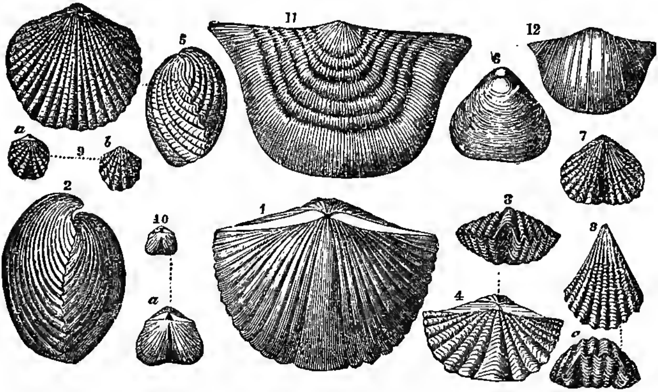
Southern part of the State; also elsewhere in certain ridges. Thickness, 500 feet.

14. Rockwood Formation. (Dyestone Group, Clinton.)

322. In East Tennessee. Variegated calcareous shales, with thin fossiliferous limestones, and thin, smooth

sandstones. From 100 to 300 feet in thickness. Contains calcareous beds highly ferruginous, which weather into a stratified and highly valuable iron ore, known as red ore or dyestone. This ore ranges in thickness

Fig. 35.



Brachiopods.—1, 2, Spirifer Niagarensis; 3, 4, Spirifer sulcatus; 5 (two views), Atrypa nodostriata; 6, Merista nitida; 7, Aoastrophia interplicata; 8 (two views), Rhynchonella cuneata; 9 *a b*, Leptocœlia disparilis; 10 *a*, Orthis bilobus; 11, Strophomena rhomboidalis; 12, Leptæna transversalis.

from a few inches to eight or more feet. A thin bed of Clinton age has been observed in Middle Tennessee.

323. The Rockwood beds, with two subordinate formations to be mentioned (the Black shale and the flinty Tullahoma limestone), constitute a trio of formations which form many small but long and characteristic ridges, "dyestone ridges," in the western part of the East Tennessee Valley. One of these lies along the base of the Cumberland Table-land and extends almost continuously from Virginia to Georgia.

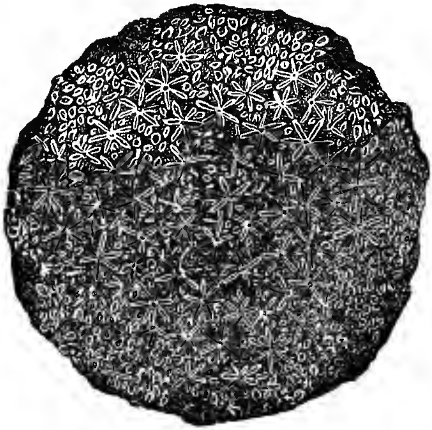
15. Clifton Limestone.

324. Named from Clifton, a town in Wayne county

on the Tennessee river. It is found in all divisions of the State. It is the Hancock Limestone in East Tennessee, where it is 450 feet thick. The formation in Middle Tennessee is 200 feet in maximum thickness.

325. In Hardin, Wayne, Decatur, and Perry the Clifton is the formation of the "glades" which are so striking a feature in these counties. The formation at many points along the Tennessee river in the counties mentioned exhibits an upper gray part and a lower red or variegated part. More or less shale is present. Fossils abound in the formation. Some of these are represented in Figs. 34, 35, and 36. The Clifton has been

Fig. 36.



called the *Meniscus* limestone, on account of the frequent presence of a fossil sponge in it. The sponge has the shape of the lens known as *Meniscus*, hence the name. It is represented in Fig. 36.

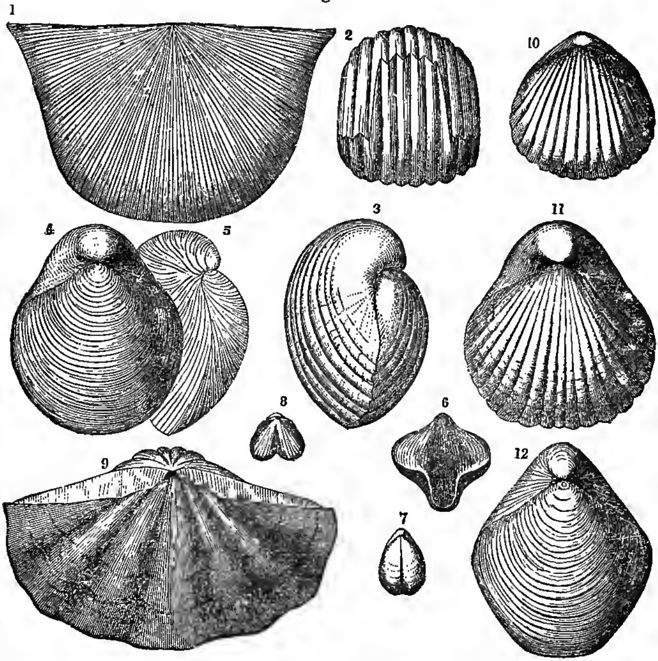
Sparry, crinoidal beds are common in this formation,

and often supply superior building material. It is largely quarried at Newsom's, Baker's, and Goodlettsville, in Middle Tennessee. This rock often has a tinge of red, and makes a fair marble.

16. LINDEN LIMESTONE. (Lower Helderberg).

326. Mostly in Middle and West Tennessee. Blue, thin-bedded limestone with shales interstratified; very fossiliferous. Greatest thickness, 100 feet. Seen at the

Fig. 37.



Brachiopods.—1, Hemipronites radiata; 2, 10, Rhynconella ventricosa; 3, 11, Pentamerus galeatus; 4, 5, Pentamerus pseudo-galeatus; 6, Eatonia singularis; 7, Meristella sulcata; 8, Orthis varica; 9, Spirifer macropleura; 12, Meristella levis.

base of the section at Linden, the county seat of Perry. Good sections of the formation, abounding in fossils, are met with at various points in the valley of the Big Sandy, in West Tennessee. Figure 37 represents some of its fossils. The formation is also seen at Decaturville and other points in Decatur county; also in the uplift of the Wells Creek Basin, in Stewart county.

327. The Upper Silurian contributes its share of economic products. Among them the bed of stratified iron ore of East Tennessee holds first place. To this we add the superior building stone supplied by the great quarries in Middle Tennessee, also fair marble and rock for making lime.

CHAPTER XIII.

Devonian Period.

328. The Devonian rocks of Tennessee, though important, have comparatively but little extent. They consist of four members which are given in their proper order in the Table of Formations, on pages 104 and 105.

The name *Devonian* is of English origin. It was first given to equivalent formations in Devonshire.

17. Camden Chert.

329. The name is given to a formation of light-colored flint or chert, which is seen in a number of counties of Middle and West Tennessee. The town of Camden, in

Benton county, is located upon the chert, and hence the name of the formation. The chert is quite conspicuous at Camden, abounds in fossils, and is 60 feet or more in thickness. Another locality is Big Sandy Station, on the Memphis branch of the Louisville and Nashville railroad. It is also seen at a number of points in the valley of the Big Sandy river and farther south. On the eastern side of the Tennessee river, in Stewart county, it occurs as one of the uplifted formations of the Wells Creek Basin. Its flint masses always contain fossils, and these bear a general resemblance to those of Fig. 37, of the underlying Linden.

In New York the formation is known as the *Oriskany*.

330. The three remaining formations of the Devonian, the *Hardin sandstone*, the *Swan Creek phosphate*, and the *Black shale*, are in some respects related. They are all more or less phosphatic; contain the remains of *fishes*; often abound in a little tongue-shaped shell named *Lingula;* and, furthermore, are locally interbedded. There are some reasons for uniting all these in one formation.

18. Hardin Sandstone.

331. A dark, fine-grained bituminous sandstone, weathering to gray or grayish yellow. Especially conspicuous in Hardin, Wayne, and Perry counties, making plateau areas and benches along the slopes. In Hardin it reaches a thickness of 12 or 15 feet; usual thickness elsewhere, one to two feet; often less, sometimes reduced to nothing. Chiefly interesting on account of its close association with the Swan Creek phosphate, the latter often apparently becoming this sandstone.

19. Swan Creek Phosphate.

332. The phosphate rock of Swan Creek, Totty's Bend, and other localities in Lewis and Hickman counties, the discovery of which adds so much to our mineral wealth and marks an era in the development of the resources of the State, is but a thickening and enriching of a stratum which is found in many counties of Middle Tennessee. In the region mentioned, the phosphate ranges in thickness from 10 to 50 inches or more, with a high average in quality. This has drawn capital, and led to the opening of many mines. Outside of this area the phosphate, for the most part, is too thin (ranging anywhere from an inch or two up to ten) or too poor in quality to work, at least under present conditions. Much phosphate of good quality, now passed over because too thin, will doubtless in the future be sought for and mined.

333. The phosphate in one variety is a dark, bluish-gray rock, fine-grained, weathering to yellowish gray, and then looking like sandstone; then again, it is lighter-colored and coarser and abounds in small spiral shells and other minute fossils. Sometimes it disintegrates and forms a white clay-like substance. Locally it may be dissolved and then precipitated, reforming into a white and variegated banded mass. Interesting varieties of the latter kind occur in Perry county. Layers of the regular phosphate are sometimes to be seen in the body of the overlying Black shale.

334. The Swan phosphate occurs like a bed of coal, lying between strata, and for this reason, as a rule, it

has to be mined like coal by driving tunnels. It is not a *residue* from the leaching of a phosphatic limestone like the Mt. Pleasant and Hudson phosphates, but is simply a bed of phosphate with very little limestone matter in it. The Mt. Pleasant and Hudson phosphates as such do not exist under a rock cover like a bed of coal or the Swan phosphate. The very conditions which give us the former phosphates require that the phosphatic limestones, their mother-rocks, should be freely exposed to the leaching atmospheric waters. Therefore we find no cover substantially over them excepting the porous soil, upon the removal of which they are mined in excavations open to the day.

The bane of the Swan phosphate, outside of favored regions, is sand, water-worn, quartzose grains of sand. It is seen half sand, three-fourths sand, or indeed all sand. Exposures of sandy phosphate are met with as much as six or eight feet in thickness.

20. THE BLACK SHALE. (Chattanooga Shale.)

335. This is a very persistent, well-known bed of black, bituminous shale; found in its proper horizon in in all divisions of the State. It is seen at many points from near the foot of Chilhowee Mountain, in Blount county, to Benton and Decatur, in West Tennessee.

336. The Black shale outcrops along the base of many mountains and ridges in the Valley of East Tennessee. It is seen, for example—and these are only two examples out of many—along the whole eastern base of Clinch mountain and along the eastern base of Cumberland mountain quite through the State from Georgia to Vir-

ginia. It outcrops along the eastern side of Sequatchee Valley from one end of the valley to the other. In Middle Tennessee it shows itself all around the sides of the Central Basin, and at many points in the valleys of the streams west of this.

In Middle Tennessee its thickness reaches 50 feet, but is often much thinner; in East Tennessee it ranges from 30 to a reported thickness of 450 feet.

337. On account of the bituminous matter present it will flame up a little when thrown on a bed of live coals, and for that reason and because it is a black shale it is often mistaken for stone coal, or is taken erroneously as an indication of stone coal. A burning fluid has been distilled from it, and some day it may be utilized in this way.

It is the source of many sulphur waters in East and Middle Tennessee, for the reason that it abounds in the mineral iron pyrites, a compound of sulphur and iron, the decomposition of which supplies the sulphur gases of the sulphur water.

338. The Black shale is a guide to the bed of the Swan Creek phosphate. The shale is generally easily found, and immediately under it is the place for the phosphate. At some points thin layers of the phosphate are interbedded, as before stated, with the lower layers of the shale.

339. Just above the Black shale is another development of phosphates in the form of rounded concretions in a bed of green shale. The consideration of this, however, comes in order under the Subcarboniferous period.

340. The chief economic product of the Tennessee Devonian is phosphate rock. This is one of great importance. The Black shale may be mentioned as a material from which copperas and alum may be manufactured.

Containing iron pyrites, it holds most of the ingredients necessary for this. We have already referred to it as the natural source of many of our sulphur waters. The Hardin sandstone has been used as a building material.

Carboniferous Period.

This period contains two subdivisions, the lower one, the *sub-carboniferous*, being made up mostly of limestones; and the upper, the *Coal measures*, made up of sandstones, shales, and beds of stone coal. The two epochs are each further subdivided into formations. These divisions and subdivisions are given in the Table of Formations, on pages 104 and 105. The student is advised to consult this table frequently,

A. SUBCARBONIFEROUS.

21. Maury Green Shale. (Ball phosphate.)

341. Resting upon the Black shale is a bed of *green* or *greenish shale* from a few inches to four and five feet in thickness. The bed is well developed in Maury county and hence the name above given to it. It has been observed in both East and Middle Tennessee.

342. The Green Shale is of interest in that it has generally imbedded in it *concretions* of calcium phosphate. These are roundish, from the size of marbles to that of a man's head, and in kidney-like, cake-like, and gourd-like forms of various sizes. They may be seen tightly packed together with little of the shale, as if so many cannon balls, in a layer from 8 to 10, or exceptionally 18 inches in thickness; or else loosely disposed in the greenish shale, which itself is more or less phosphatic. The concretions, when broken, give out a strong fetid odor and show shells of lingulæ. They contain 50 to

65 per cent of calcium phosphate. The bed is well developed in parts of Perry county.

Kidney forms of the above kind are now and then seen imbedded in the underlying Black shale.

343. Summary of Tennessee Phosphates and Where to Look for Them.—Looking back in review, we find that there are in Middle Tennessee four distinct and independent horizons of available phosphate, and in addition a fifth occurrence comprising irregular deposits formed—travertine-like—by precipitation from solution.

344. The following is a list of the phosphates:

1. The *Mt. Pleasant*, of *Nashville or Trenton age.* Occurs over a wide extent of country; rock of high grade, mined cheaply in open excavations; production great and increasing.

2. The *Hudson*, of the *Hudson* or *College Hill Age.* Its horizon is near, or at the top of the Lower Silurian limestone and from 100 to 200 feet above the Mt. Pleasant rock. Near and north of Nashville it is found at the tops of the hills; occurs in large quantities in Sumner county; also in Hickman county, occupying a lower level, and, like the Mt. Pleasant, mined in open excavations; production considerable and increasing.

3. The *Swan Creek*, a division of the *Devonian Period.* Lying in the hills, like a bed of stone coal, and but little above the horizon of the Hudson, in fact, at Totty's Bend, in Hickman, it lies upon the Hudson. Westerly from this the Niagara limestone soon wedges in and separates the two. Mined, for the most part, like stone coal, by a system of tunnels and underground rooms.

4. The imbedded *phosphate concretions* of the Maury Green Shale make the fourth horizon. This is *Subcarboniferous;* lies at the base of that division and right above the Black shale. If the balls were mined in large quantities, it would be mostly by tunneling. They have been used but little, having been thrown out of consideration by the other abundant and superior phosphates.

5. *Perry County Phosphate.* This white and variegated phosphate occurs in valleys in Perry county and belongs to no especial geological horizon, as its masses have been deposited from water on the rocks of several formations. Sometimes the Perry county phosphate presents itself in handsome marble-like pieces, *not* mixed with foreign matter; then again it is a medley of white mineral with broken chert. It occurs in large quantity, and parties have been industriously quarrying it out for market.

22. Tullahoma Limestone. (Siliceous Group in Part; Fort Payne Chert; Barren Group.)

345. Excluding the Maury Green Shale just described, the Tullahoma formation embraces the lowest strata of the Subcarboniferous rocks. The rocks embraced are varied in character and outcrop in all divisions of the State, but most extensively in East and Middle Tennessee. The formation is that of the highland "Barrens" of Moore, Coffee, Cannon, and of all the other counties immediately around the Central Basin. In East Tennessee, the chert of the dyestone ridges and the sandstones and shales (Grainger shale) of Poor Valley ridge east of Clinch mountain and of other allied

ridges belong to it. West of Nashville, it includes the Erin Burry limestone of Houston county and the siliceous Harpeth shale of the bluffs of Harpeth river and Turnbull creek in the vicinity of Kingston Springs. Were this the place, other special beds and phases of the formation might be mentioned. As a whole the flinty and siliceous character of the Tullahoma is well marked, making the formation a siliceous or a calcareo-siliceous substratum or base for the whole Carboniferous system of Tennessee.

346. The thickness of the series varies from 200 to 600 feet, and, exceptionally, at one locality in East Tennessee to 1,200 feet. Its most common rock is cherty or flinty limestone, the chert often in thick layers. In regions where the strata have been leached, the calcareous part of the rock has been removed and the chert left in masses of heavy flint layers.

347. Tullahoma is located upon the formation, and hence the name given to it. The cherty limestone is grandly seen in the gorges of the cascades within easy drives of the town. About the town and down the railroad grade to Normandy, siliceous residues of the leached formation are plentiful; about the town, siliceous shales and sandstones; and, down the grade, characteristic masses of the heavy chert layers. This chert is the hard brow that all around crowns the steep sides and overlooks the floor of the Central Basin.

The following county seats are located on the Tullahoma formation: Manchester, Smithville, Ashland, Centerville, Erin, Linden, and Waynesboro.

23. St. Louis Limestone.

348. This limestone, called *St. Louis* for the reason that layers of the same age outcrop about that city, is, with the beds of the Tullahoma formation, the surface or cap formation of the Highland Rim. In the flat wooded regions immediately around the Central Basin the rocks of the Tullahoma formation are first met with, but going farther back from the Basin the overlying layers of the St. Louis begin to appear. At the same time the character of the country changes, the soil becomes red and much more fertile, presenting, indeed, some of the best farming regions in the State. The rocks are gray and blue, thick-bedded, fossil-bearing limestones, usually with nodules of chert and from 250 to 300 feet thick.

349. A wide belt of country lying at the western base of the Cumberland Table-land, and including the towns of *Livingston, Cookeville, Sparta, McMinnville, Cowan,* and *Winchester,* is based on the St. Louis limestone. In the counties of Robertson, Montgomery, and Stewart, north of the Cumberland River and contiguous to the Kentucky line, is another large section, including much excellent land, which is based on the same rocks. Within this are the towns of *Springfield, Clarksville,* and *Dover.* Other towns located on the St. Louis limestone are *LaFayette, Charlotte, Waverly, Newberg, Waynesboro,* and *Lawrenceburg.*

350. Wherever this formation underlies the surface it is common to see porous flinty masses and more or less angular gravel scattered over the ground or mixed with the red soil. Such regions also are remarkable for "sink holes," underground streams, and caves.

351. Fossils abound, and conspicuous among them is

a large coral bearing the long name of *Lithostrotion canadense.* In Fig. 38 end and side views of a piece of the coral are presented.

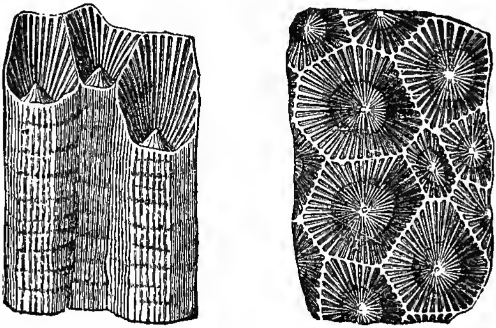
In East Tennessee the St. Louis limestone has less importance, and it and the Tullahoma are considered together as one formation.

Many valuable iron ore banks in Middle Tennessee rest upon this and the Tullahoma limestone.

24. Mountain Limestone.

352. Resting upon St. Louis limestone, and forming the base of the Cumberland Table-land, is the *Mountain*

Fig. 38.

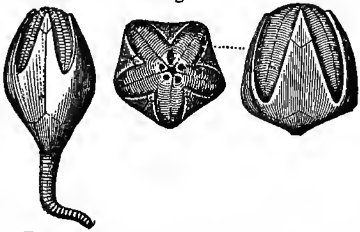


limestone. Its layers outcrop on the slopes of the Table-land on all sides. The long tunnel on the Nashville & Chattanooga railroad is cut through this limestone, and the Sewanee railroad, in ascending the mountain, presents a fine section of its layers. The group includes a few beds of shale, one of which, near the top, is brown or reddish, and another pale green. In the southern part of the State the entire formation is 700

feet thick, but near the Kentucky line it is reduced to about 400.

353. The Mountain limestone is well filled with fossils, among which the remains of fishes, especially teeth, are not rare. In Fig. 39 two kinds of crinoids are represented, which are frequently found in these rocks, and are sometimes thought to be "petrified hickory nuts." They are the remains of animals, however, and not nuts.

Fig. 39.



Crinoids.—1, Pentremites pyriformis; 2, 3, Pentremites Godoni.

354. The Mountain limestone makes the base of Lookout mountain. Several belts or strips of it occur, with the Tullahoma formation and the Black shale, in the Valley of East Tennessee at considerable distances from the Table-land. They are found severally on Newman's ridge east of Sneedville, east of Clinch mountain, east of White Oak mountain, and at Montvale Springs, in front of Chilhowec mountain. At the base of the latter mountain, and running near the springs, is a tremendous fault or displacement of the formations, by which strata once 10,000 feet apart vertically are brought together. A great fissure was formed and the rocks on one side sunk bodily that number of feet down. On one side of the fault is the top part of the Ocoee conglomerate, and on the other the Mountain limestone.

355. The Subcarboniferous supplies phosphate rock in the Maury green shale, a great variety of building stones, rock for roads and for making lime, lithographic stones, petroleum, salt brine, saltpeter earth and epsom salts in

caves, as well as cabinet specimens of crystallized gypsum, alabaster, barite, quartz, calcite, and dolomite.

CHAPTER XIV.

B. COAL MEASURES.

356. In these measures we have the coal beds of Tennessee. They are a series of interstratified and alternating sandstones, conglomerates, shales, and coal beds. The Coal measures form the cap or top part of the Cumberland Table-land, and have therefore the same horizontal extent, equal to 5,100 square miles. This is the Tennessee coal field.

357. The following section of the strata in the vicinity of the Tracy City coal mines will give a good idea of the character and alternation of the rocks of coal measures. The lowest beds outcrop just above the Mountain limestone in a deep "gulf" about two miles south of Tracy City, and the section includes all the strata in succession from these to the highest points on top of the Table-land near the mines. It commences with the lowest and ascends:

Bon Air or Lower Measures.	(1) Shale and sandstone	40 feet.
	(2) *Coal* of variable thickness	1 to 3 feet.
	(3) Hard sandstone, often shale	78 feet.
	(4) Sandy shale	22 feet.
	(5) Shale with a few inches of hard clay at top	8 feet.
	(6) *Coal*, outcrop from	½ to 1½ feet.
	(7) Sandstone	65 feet.
	(8) Shale, with clay on top	10 feet.
	(9) *Coal*, outcrop from	½ to 1 foot.
	(10) CONGLOMERATE	70 feet.

Tracy City Measures, a part of the Upper Measures.

(11) Sandstone,	17 feet.
(12) Shale	3 feet.
(13) *Coal* outcrop	1 foot.
(14) Shale, some of sandy	33 feet.
(15) *Coal*, worked at the Sewanee mines	3 to 7 feet.
(16) Shale, more or less sandy, sometimes sandstone	45 feet.
(17) Sandstone	86 feet.
(18) Sandy shale	25 feet.
(19) Clayey shale	1 foot.
(20) *Coal*, outcrop	½ foot.
(21) Shale	23 feet.
(22) *Coal*, a few inches.	
(23) Sandstone and conglomerate, at the top	50 feet.

358. The greatest thickness of coal measures in Tennessee is to be found in the State's Brushy Mountain coal field. The field lies in Morgan county, and its mountains are a part of the great bed of mountains so conspicuous in Morgan, Anderson, Claiborne, and Scott. The Brushy mountains and their deep foundations are coal measures from top to bottom, with strata nearly horizontal. A drill driven down vertically from one of the peaks to the limestone at the base would penetrate sandstones, conglomerates, and shales, with interbedded coal beds for a distance of nearly 3,000 feet.

359. Chiefly from a topographical point of view, the series is best divided as in the Table of Formations. Commensing with the lowest, they are briefly characterized as follows:

1. *The Bon Air Measures*, the lowest division, forms the great cap of the mountain, and in area is coextensive with both mountain and coal field. The cap is a conglomerate sandstone—a sandstone containing white, water-worn, quartz pebbles.

2. *The Tracy City Measures,* the second division, and resting often on the first as a floor; limits narrower; confined greatly to back ridges or plateau ridges on the mountain.

3. *The Brushy Mountain Measures,* the third division, in turn resting on the second, is confined to the northeastern counties of the coal field; its strata, containing many beds of coal, well seen in the high mountains of Anderson, Morgan, and the counties north of these.

25. Bon Air Measures.

360. This, the lowest divisiou, rests immediately upon the Mountain limestone. It is a series of sandstones, shales, and coal, ending above with a great conglomerate. The conglomerate, the topmost stratum of the division, is known as the *Sewanee conglomerate,* for the reason that Sewanee, the site of the University of the South, is located upon it. This stratum makes the flat top or floor of a large part of the Cumberland mountain.

361. The Bon Air measures, so called from the important mines of the name in White county, have a thickness from the limestone to the top of the conglomerate of from 250 to 500 feet, and contain from one to four seams of coal, or horizons in which coal may be looked for. The coals are not always present in workable thickness, but one or two of them often become, over wide areas, most valuable beds of coal. Such, for example, are the beds of Fentress, White, and adjoining regions, which are prized for their quality and extent. At points all along the western side of the Cumberland mountain these lower coals are mined.

362. On the eastern side of the mountain they are also mined at various points, being often of good thickness and quality. At Harriman, in Roane County, two coals of the division are exposed in a cut of the railroad at Big Emory gap, one of which at least has been worked. The same coals appear in Walden's ridge, north of Harriman.

363. The Bon Air measures, being the lowest division of the coal measures, have necessarily great extent, equal to the area of the whole coal field. They undoubtedly run under the Brushy mountains, supplying the lowest coal horizons of that region.

26. Tracy City Measures.

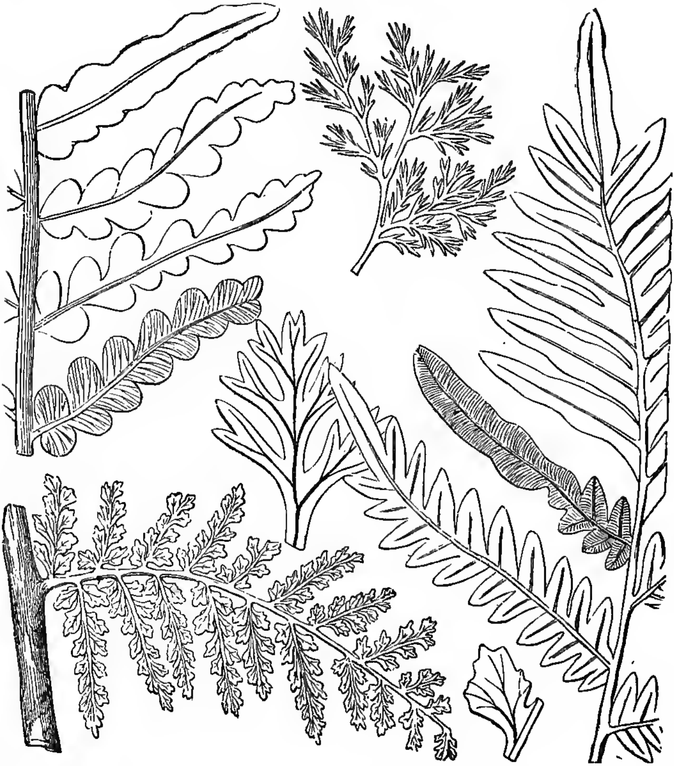
364. This, the second division of the coal measures, is named from Tracy City, the center of extensive mining operations in the chief coal bed of the division, the "Main Sewanee." This division, much like the first, is a series of sandstone, shales, and coal, surmounted by a heavy sandstone. This series is from 250 to 500 feet thick, and is found in flat-topped, terrace-like ridges on the mountain, especially on its western half. These ridges lie back greater or less distances from the edge of the mountain, and are often spoken of as "back ridges" or as benches.

The division contains from three to five seams of coal or coal horizons. It is not common to find all or the most of them workable at any one point, but if not workable at one place, they may be at another.

365. The most important seam or bed of coal in the

division is the "Main Sewanee" of the Tracy City region. It extends in good thickness over wide areas of the coal field. It is mined largely in Marion county, is a chief coal in Sequatchee, Bledsoe, White, Cumber-

Fig. 40.



land, Morgan, and counties north. It is one of the coals, though often called by a different name, of the mines along the eastern edge of the mountain in East Tennessee. It is the coal of Rockwood in Roane, and is

seen in the railroad cut at Big Emory gap and at other points north of this.*

Besides the "Main Sewanee" other coal beds of the division have local interests and are the seat of mining operations, but we need not dwell upon them here.

366. The Tracy City measures, having their limits often within the edges of the mountain, have an area estimated to be at least one-third less than that of the Bon Air division. Like the Bon Air, these measures, with their coal horizons, run under the Brushy Mountains.

367. Coal has been formed, as stated, from beds of vegetable matter. The shales both above and below the coal seams often contain the impression of leaves, among which occur also remains of fruits, branches, and even trunks of trees, the kinds of which, together with some of the kinds of animals living when the plants grew, are mentioned in the paragraph just referred to. In Figure 40, on the opposite page, are representations of leaves of ferns found in the coal shales.

27. Brushy Mountain Measures.

368. These, the third division of the Tennessee coal measures, are a vast body of shales and sandstones, including not less than fourteen coal horizons, half of

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*The Queen and Crescent railroad, in passing northward through the water gaps of the Big Emory river at Harriman, in Roane county, cuts through the highly inclined strata of Walden's ridge, and instructively displays a continuous section of the rocks and coals of both the Bon Air and Tracy City measures, as there existing. The section is terminated by a great sandstone, which we name the *Emory sandstone.* The Emory may be taken as the topmost stratum of the Tracy City measures.

which at least are coal beds of workable thickness. All these coals are contained in the property of the State, and in the mountains mostly above the water level of the region. Thickness, not much, if any, below 2,000 feet.

369. The topography of the Brushy Mountain measures is not of the flat-topped or plateau type, like that of the Sewanee and Tracy City measures; it is that, rather, of high, dividing, winding ridges with sharp crests, the ridges rising as mountains from 1,400 to 1,800 feet above their bases, and 3,200, more or less, above the sea.

370. The coal resources of the Brushy Mountains, as great as they are above water level, are supplemented, below this level and beneath the mountains, by the coals of the Bon Air and Tracy City measures. These latter will be reached by means of shafts.

371. Thus it is seen that all the coal horizons in Tennessee are represented, some above and some below water level, in the Brushy Mountain lands.

372. Besides stone coal, the Coal measures of the State yield an unlimited amount and variety of building stones, flagstones, and the like. Valuable beds of fire clay and potter's clay occur at many localities. Iron ores in the form of *clay-iron-stone* and *blackband* are met with, but so far have received little attention.

Towns located upon the coal measures are Huntsville, Jamestown, Allardt, Bon Air, Montgomery, Wartburg, Crossville, Spencer, Altamont, Tracy City, Mont Eagle, Sewanee, and other smaller ones.

CHAPTER XV.

The Mesozoic and Cenozoic Eras of Tennessee.

373. It remains to consider the formations of the State included in the Mesozoic and Cenozoic Eras. These are, in the main, confined to West Tennessee, and embrace strata very different in appearance from those we have been studying. In the place of hard sandstones, limestones, and shales, we have now beds of sand, clays, and marls, that have never been hardened, with some local exceptions, into what are popularly called *rocks*. These unconsolidated strata are the Tennessee representatives of the two great geological eras mentioned.

374. It has been stated that the Gulf of Mexico once reached up as far as the mouth of the Ohio, and that from these waters the strata peculiar to West Tennessee were deposited. The part of the *old shore* of the Gulf that was in Tennessee is easily traced out. It extends from Mississippi to Kentucky in a northerly and southerly direction, coinciding with the Tennessee river through a part of Hardin county, but elsewhere a few miles west of that stream. The towns of Camden and Decaturville are but a short distance from it. Along this line the older strata of Tennessee and the younger strata peculiar to West Tennessee come in contact. The first are abruptly beveled off to an unknown depth, presenting their edges to the west; the latter were deposited so as to overlie the beveled and sloping edges of the first.

IV. MESOZOIC ERA.

Cretaceous Period.

375. The Cretaceous formations are confined to West Tennessee and to a belt of country lying in Hardin, McNairy, Decatur, Henderson, and, doubtfully, small parts of Carroll, Benton, and Henry. This belt is sixteen or more miles wide where it enters Tennessee from Mississippi, but in its northward extension contracts in width and is much reduced when reaching Kentucky.

Its exact northern limit remains to be determined. Its formations are:

(*a*) *Coffee Sand.* A heavy bed of laminated sand, containing clayey leaves and layers; 200 feet thick.

(*b*) *McNairy Shell-bed.* A stratum made up of sand, clayey and calcareous matter. It contains green grains and fossil shells in profusion; 350 feet thick.

(*c*) *Ripley.* Much like the Coffee sand; perhaps 400 feet thick.

28. The Coffee Sand. (Eutaw.)

376. This is the lowest of the cretaceous beds outcropping in West Tennessee. It is a group of stratified sands, containing scales of mica. Interstratified more or less with these sands are thin, often paper-like layers of dark clay, the clayey layers sometimes predominating. Occasionally beds of laminated or shaly clay of considerable thickness—from one to twenty feet or more—are met with in the series. The group contains in abundance woody fragments and leaves, converted more or less into the half-formed, imperfect kind of coal called *lignite.*

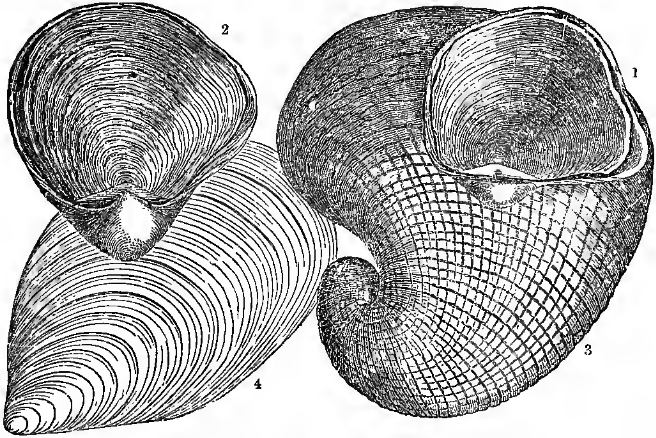
377. The layers of the Coffee sand are well exposed in the bluffs on the Tennessee river, in Hardin county, as at *Coffee*, *Crump's*, and *Pittsburgh* landings. From the first of these the formation gets its name. The bluffs are made up of these layers, with the exception of a covering of gravel on top of them, belonging to the Lafayette formation, to be described. They are seen also at Scott's Hill, on the road from Lexington to Clifton. Decaturville is in part upon their outcropping edges.

29. McNairy Shell-bed. (Green Sand.)

378. This formation is sometimes called *rotten limestone*, because it has the appearance, especially in Alabama and Mississippi, where it also occurs, of a soft,

chalky limestone. Its mass consists of fine quartzose sand mixed with clay and much calcareous matter. The mass contains also the *green grains* of a mineral called

Fig. 41.



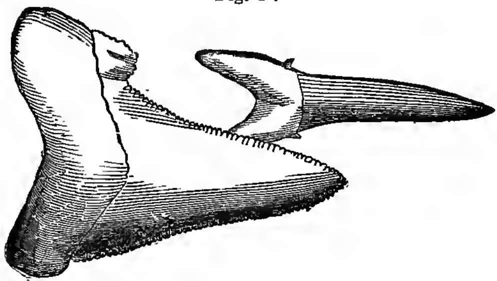
Mollusks.—1, Gryphæa vesicularis; 2, Gryphæa Pitcheri; 3, Exogyra costata; 4, Inoceramus problematicus.

glauconite, and layers rich in this may be used as a fertilizer. These grains are soft, and were they black would closely resemble the grains of gunpowder. They give a greenish color to the stratum, and hence the name, *green sand*.

379. The McNairy formation contains in abundance fossil shells of many varieties, some of which are of large size. Among them are great oyster shells, which have been abundant enough at some localities to gather and burn into lime. In Fig. 41 are reduced representations of some of the large shells. Nos. 1, 2, and 3 are oyster shells, the first two of which are found at many localities. They are, with other shells and fossils, among which are sharks' teeth (Fig. 42), very conspicuous on the "bald hills," or "bald places," of the counties in which the formation

outcrops. The bald hills are marly places, often bare, or with but little vegetation.

Fig. 42.



Sharks' Teeth.

This formation is the northern extension of the *rotten limestone* of Alabama and Mississippi. It lies in a belt extending through the eastern parts of McNairy and Henderson counties, and the extreme western parts of Hardin and Decatur. Its maximum thickness, 350 feet, is in McNairy.

30. Ripley.

380. It is undetermined as yet as to whether the Ripley formation of Mississippi extends into Tennessee. Most of what was known as Ripley is now thrown into the succeeding division, the Middleton. There is a belt of chiefly stratified sands, a few miles in width, contiguous to the western border of the McNairy shell-bed, and running north and south through the State, that may belong either here or to the Middleton. This is a question to be settled by fossils when they can be found.

V. CENOZOIC ERA.

Eocene Period (Lower Tertiary).

381. The strata belonging here are mainly laminated sands, often mica-bearing; interstratified, dark, shaly clays and lighter

clays occur, but more frequently sandy beds laminated with thin clayey seams. Lithologically the series resembles that of the Coffee sand; often contains leaves, pieces of lignitic wood, and here and there, especially in its westerly part, beds of lignite. Special strata occurring are named below.

Eocene beds extend from the western margin of the Cretaceous over the greater part of West Tennessee to the bluff escarpments overlooking the bottom of the Mississippi. But they do not outcrop over the whole of this area. In many sections much of their surface is concealed underneath a cover of certain sands and loams of later formations.

The divisions are as follows:

(*a*) *Middleton*, below;
(*b*) *La Grange*, above.

31. MIDDLETON FORMATION. (Ripley in part; Porter's Creek; Flatwoods; Clayton; Midway.)

382. A formation having the general lithological character of the Eocene—laminated sands and clays, as above. In Hardeman the following are special beds: a limestone (Turritella limestone) from two to six feet thick; a clayey, calcareous sand, containing green grains and shells (green sand); and a clayey or clay-spotted sandstone, holding scattered green grains and impressions and molds of shells, from two to four feet thick. Above these, and outcropping on the west of them, is a great bed of laminated or shaly clay (soapstone), from 100 to 200 feet thick. This bed extends, nearly north and south, through the State. Huntingdon and Paris are in part located upon it.

The thickness of the Middleton may be placed at from 400 to 500 feet.

32. La Grange. (Lignitic; Bluff Lignite.)

383. Beds of this division crop out at the base of the noted section at La Grange, Tenn., and come out from under a great mass of the Lafayette formation. The beds outcropping here are sharp, mica-bearing sands and thin sandstones, the latter showing leaf impressions.

384. The La Grange is in general, like most of the Tennessee Eocene, grayish sand, often with clayey seams and dark with vegetable matter; contains, locally, beds of light-colored clays—as the leaf-bearing clays at Grand Junction; holds also beds of lignite at many points; formation outcrops at the base of the escarpments overlooking the bottom lands of the Mississippi. It extends over a large part of West Tennessee, but is concealed to a great extent, in common with most of the Eocene, as stated, by a cover of later beds.

385. The La Grange is a heavy series. At Memphis the artesian test borings descended into it for 1,115 feet, there being first at the top, a bed of stiff clay 145 feet thick, laminated and containing leaves and lignitic matter; then 800 feet of sand with little clay; then sand and clay beds alternating to the bottom.

It may be that the lower sands and clays pierced by the test borings may belong to formations underlying the La Grange, as the Claiborne of Mississippi or the Midway.

386. The clay beds of the formation are of much economic importance.

387. Impressions of leaves are frequently met with in this formation. Many of the leaves do not belong to species now exist-

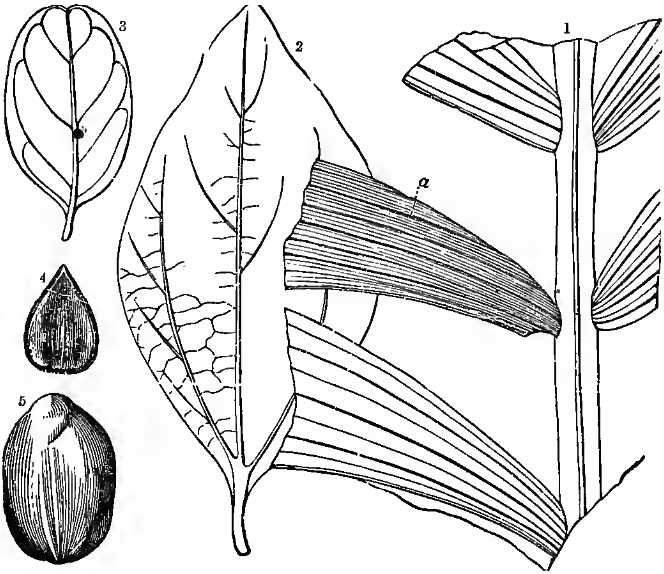
ing, and many to genera which grow only in tropical regions. Some of the vegetable remains are represented in Fig. 43, on this page. No. 1, an oak leaf, and No. 4, a beechnut, were found near Somerville, Fayette county.

NEOCENE PERIOD (UPPER TERTIARY).

33. LAFAYETTE. (Orange Sand.)

388. In West Tennessee a wide-spreading formation of orange, reddish, yellow and white sands, often including

Fig. 43.



1, Quercus (Oak) myrtifolia; 2, Cinnamomum (Cinnamon) Mississippiense; 3, Calamopsis (Palm) Danæ; 4, Fagus ferruginea (a Beechnut); 5, Carpolithes irregularis (also a nut).

beds of gravel. The sands are generally loose, but there are frequently present brownish layers of sand, from 1 to 10 feet or more in thickness, compacted and hardened

more or less by ferruginous and clayey matters. It is the formation seen in road cuts, in washes and gullies of old fields and in the bluffs of streams. It is made conspicuous by its orange and otherwise colored sands.

389. It includes the sandstone caps of many high points in West Tennessee; also "hollow rock" of Hollow Rock Station; the iron ores west of the meridian of Nashville; and the upland gravels bordering the rivers in East Tennessee. Many towns in West Tennessee, like Jackson and McKenzie, are partly located upon it.

The formation yields as building material brown sandstones and a superior sand, the latter used in Nashville.

We have placed the Lafayette here; some think it Pleistocene; as to which it is remains to be determined.

Pleistocene Period (Quaternary).

390. The following are the two Tennessee divisions of the Pleistocene:

(*a*) *Memphis loess;*
(*b*) *Milan loam.*

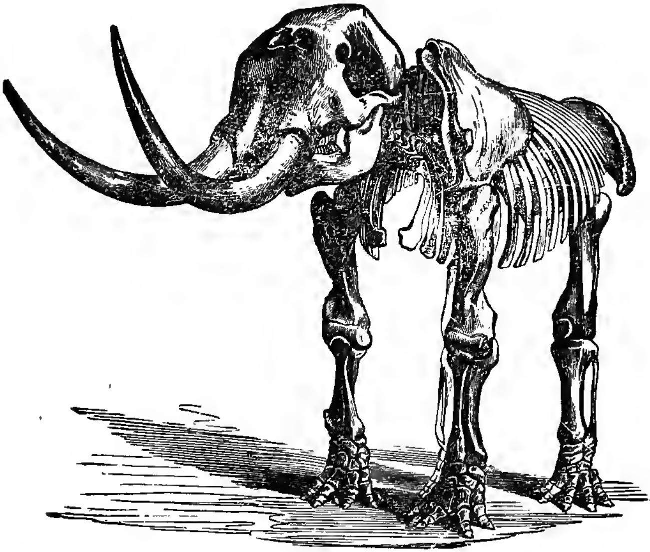
34. Memphis Loess. (Bluff Loam.)

391. The formation upon which the most of the city of Memphis stands. It consists of a fine siliceous earth or loam, more or less calcareous, and of a light ashen, yellowish, or buff color. It is quite compact; railroad and street cuts through it leave vertical walls which stand for months, or even years, as if so much rock.

392. The belt of it extends from Mississippi to Kentucky, and includes in its area the rich and productive

uplands of Shelby, Tipton, Lauderdale, Dyer, and Obion. The county seats of the above counties are upon it. Maximum thickness, 100 feet. It thins out to a feather edge to the east of the counties mentioned.

Fig. 44.



393. The Loess belongs to the Pleistocene. Bones of the *mastodon*, (M. Americanus), the skeleton of which is reprepented in Fig. 44, have been found in the formation. Remains of this animal occur also in the later alluvial deposits at localities in all three divisions of the State. The name of another animal, the remains of which have also been found, is *megalonyx*. This was of the sloth kind, and allied to the great *megatherium*, represented in Fig. 45.

35. MILAN LOAM. (Yellow Clay Loam.)

394. A mellow clay without laminar structure, of light yellow or pale reddish color; containing more or less fine

sand; variable in thickness from a few inches to 10 or 15 feet, averaging about 3 feet; covers very generally the sands of the Lafayette, and is the basis of the best subsoils and soils of the upland parts of many counties in West Tennessee.

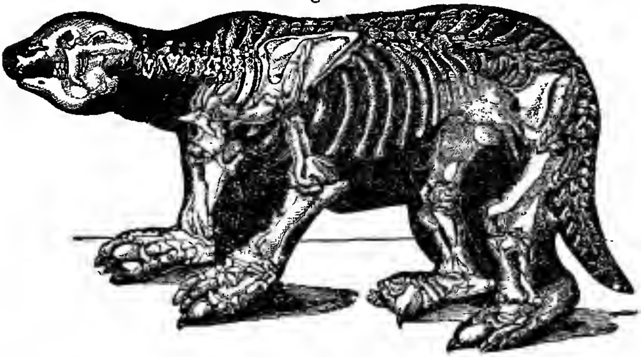
Can be studied in and around Milan, Gadsden, McKenzie, and at numerous other points.

Recent Period (Quaternary).

36. Alluvium.

395. Includes chiefly river or fresh water deposits

Fig. 45.



that have accumulated in historic time and are now accumulating. The clays, sands, and alluvial material of river flats and bottoms belong here. Lands generally mellow and rich, yielding abundantly. The most extensive alluvial areas in Tennessee are those of the Mississippi river. Next in extent come those of the Tennessee. Lake county, in the northwestern corner of the State, is wholly within the alluvial area of the Mississippi.

PART IV.

ECONOMIC GEOLOGY.

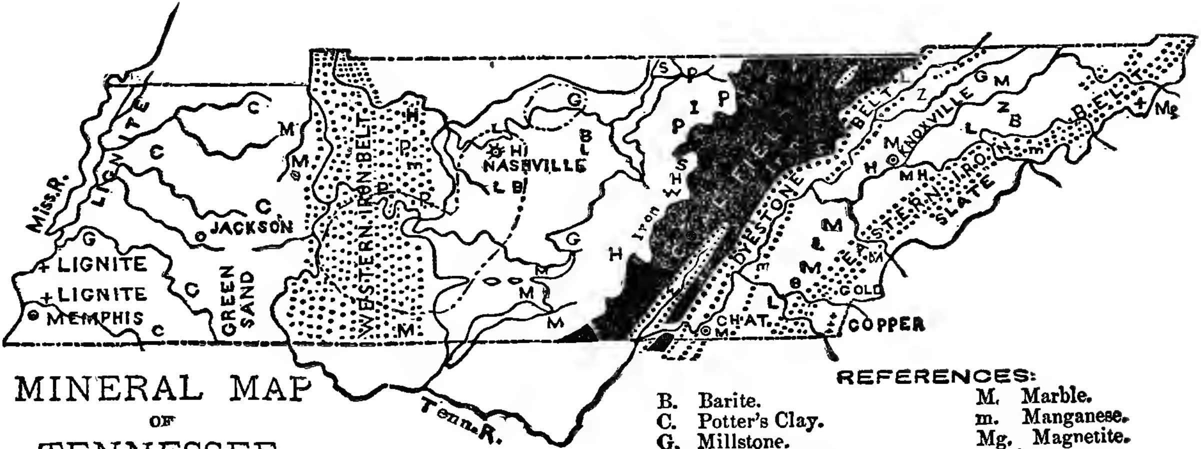
396. A knowledge of economic geology is of prime importance to every citizen of the State. It treats of substances that bear directly on the arts, industries, and progress of the human race. A generally diffused knowledge of the quantity, quality, and localities of those substances that underlie individual and national prosperity cannot fail to exercise a beneficial influence upon the people of the State.

The mineral map, on next page, will designate the locality of the valuable minerals in the State. The student would do well to study this map until he is familiar with the coal area, the iron belts, the regions of copper, zinc, phosphate, marble, and other substances which are treated of in this part.

CHAPTER XVI.

Coal Area, Coal, and Coal Mines,

397. Coal and Coal Fields.—Coal is classed as a mineral, though it is of vegetable origin. It is the most important of all the mineral products of Tennessee. The coal region of Tennessee is embraced in the great Appalachian coal field, which extends in a northeasterly and southwesterly direction for a distance of 875 miles, through the western part Pennsylvania, the eastern part of Ohio, the western corner of Maryland, embracing nearly all of West Virginia and the eastern part of Kentucky, crossing Tennessee, and ending near Tuscaloosa, Ala. It embraces a productive coal area of



MINERAL MAP OF TENNESSEE.

REFERENCES:

B. Barite.
C. Potter's Clay.
G. Millstone.
H. Hydraulic Limestone.
I. Iron.
L. Lead.
—.—.. Phosphate Deposits.
M. Marble.
m. Manganese.
Mg. Magnetite.
P. Petroleum.
S. Salt.
W. Whetstone.
Z. Zinc.

59,105 square miles. This is ten times the area of the productive coal fields of Great Britain, and eight times as great as all the explored coal fields of the remainder of Europe.

398. Of this coal field Tennessee has about 5,100 square miles. It includes the counties of Morgan, Scott, and Cumberland; the greater parts of Fentress, Van Buren, Bledsoe, Grundy, Sequatchee, and Marion; considerable portions of Claiborne, Campbell, Anderson, Rhea, Roane, Overton, Hamilton, Putnam, White; and small portions of Warren and Coffee. The area of coal, in other words, embraces the whole of the Cumberland Table-land, the third natural division of the State. Its area is represented on the mineral map.

We have already spoken briefly of the leading physical features of this division. The student will remember that the edges of the table-land are made prominent and striking by a bold cliff, resembling a huge, massive wall running along near the top of the mountain. This cliff is the outcrop of a conglomerate rock averaging seventy feet in thickness.

399. The economic coals of Tennessee may be divided into three groups:

(1) Bon Air, the lowest, which contains two workable seams and some smaller ones. This group lies under the conglomerate rock.

(2) The Tracy City, which contains two workable seams and occurs in the plateau ridges resting on the general top of the table-land above the conglomerate rock.

(3) The Brushy Mountain group, which rests upon all other divisions, and contains about fourteen seams of coal, one-half of which are workable.

400. The Bon Air coal is worked, or occurs mainly in Fentress, White, Van Buren, and Roane, as well as at Sewanee and other places on the western edge of the table-land.

The Tracy City group is found in the greatest force in Grundy, Marion, Sequatchee, Bledsoe, Cumberland, Roane, and counties along the eastern edge of the mountain.

The Brushy Mountain group has its development in parts of Morgan, Anderson, Campbell, and Scott counties.

401. By coal measures is meant a series of strata in which the seams of coal occur. The seams of coal form layers (not veins) like the layers of limestone and other sedimentary rocks. Beneath all the seams are beds of bluish or gray clay, which, in some cases, were the soils upon which the plants are supposed to have grown that supplied the material for the formation of the coal. Above the coal are usually bluish or black shales which split easily. They contain beautiful impressions of coal plants, the study of which supplies important data to geological students.

402. The Bon Air Coal Measures rest immediately upon the massive mountain limestone, which extends one-third, and sometimes two-thirds, the way up to the cliff-forming conglomerate. Immediately upon the limestone, and between it and the conglomerate, rest strata of shales and sandstones, with three, and rarely four, seams of coal. The coal seams of the Bon Air measures are not uniform in thickness, but variable and irregular, sometimes thinning out to a few inches, and then again swelling out into masses or pockets six or seven, and

even twelve, feet thick. The coal, however, is usually of excellent quality.

403. **The Tracy City Measures** make hills, ridges, and even mountains, resting upon the main conglomerate, and contain two workable seams of coal.

A seam of coal is workable when it is over two feet thick.

404. **The Brushy Mountain Measures** rest upon the Sewanee Measures, are fully 2,000 feet in thickness, and contain more seams of workable coals than both of the others together.

405. Along the eastern edge of the coal field, in all the coal measures, the seams are thrown up with the other strata into folds or flexures. These flexures are seen in the coal mines at the Rockwood and in a few other mines. In connection with these folds or flexures faults occur which displace the strata, and occasionally interfere with mining.

406. Deep ravines are cut into the coal field, and these are of great value in opening the coal, making it accessible and easy to mine from horizontal entries. The Sewanee coal mines have this advantage, as well as nearly all the coal mines in the State. A large part of the coal field contains all the coal measures.

407. In parts of Anderson and Claiborne counties the main conglomerate sinks below the level of the valley; nevertheless the mountains here are much higher than in any other part of the coal field, and the seams of coal are more numerous.

408. **Quantity of Coal.**—It is estimated that a coal bed

one foot thick will yield 1,000,000 tons of coal to the square mile. The coal seams of Tennessee, all placed together, would make a bed eight feet thick all over the coal field. This would give 8,000,000 tons to the square mile, or 40,000,000,000 tons for the State. The present rate of consumption is about 3,000,000 tons annually. At this rate it would take 13,000 years to exhaust our coal supply.

409. Quality of Tennessee Coal.—There are two leading varieties of coal known to commerce—viz., *bituminous* and *anthracite.*

Bituminous coal yields, when heated, a mineral tar, and also an inflammable gas. This mineral tar burns like bitumen, with a yellow, smoky flame, giving out the same odor, and hence the name. There is no bitumen in the coal, but bituminous substances are formed by the action of heat, just as the gas is made which lights our cities.

410. Anthracite has been derived from bituminous coal by the action of subterranean heat under pressure. In this way it has lost most of the elements which form by heat its bituminous or flame-making substances. It is, indeed, a sort of native coke.

411. All the coals of Tennessee belong to the bituminous kind. These are variable in their yield of bituminous substances. Those coals yielding the largest quantity are valuable for making gas. Bituminous coals may be classified into coking,* non-coking, and cannel coal.

412. (*a*) Coking coal softens and becomes a pasty or

*Coking and caking coals are synonymous.

semi-liquid mass in the fire, from which bubbles of gas escape. When the volatile products have been drawn off in partially closed ovens, the fritted mass which remains is called coke. This is used in the manufacture of iron.

413. (*b*) Non-coking coal does not soften under heat. Under this may be included cherry, or soft coal, which ignites readily and burns rapidly; splint or hard coal, which ignites and burns less freely. Free-burning coals are those which do not coke, while the coking coals are sometimes called binding coals.

414. (*c*) Cannel coal, or Parrot coal, is compact, even in texture, and of a dull black color, and has not the banded structure seen in other coals. Some varieties, when ignited, burn like a candle, from which it takes its name. It yields a large proportion of bituminous oil, which is sometimes distilled out of it and used as a coal oil, or burning fluid.

415. The most valuable constituent of coal is carbon, and coals are valuable in proportion to the amount of carbon they contain, setting aside impurities. Thirteen samples of Tennessee coal, taken from various mines, show an average of 63.17 per cent of carbon, 30.42 per cent of volatile matter, and 6.46 per cent of ash.

416. Iron pyrite, or pyrites (often called sulphur), and slate injure the quality of coal. The coals of Tennessee are remarkably free from such impurities.

II. Coal Mines and Coal Product.

417. During the year 1898 there were 73 coal mines in the State, 61 of which were in active operation, which produced in

the aggregate 3,022,896 tons of 2,000 pounds, valued at $2,337,512. Campbell county has 15 mines; Anderson and Grundy, 11 each; Marion and Morgan, 8 each; Scott, 6; Claiborne, 5; White, Hamilton, and Rhea, 3 each; Roane, 2; and Putman, 1. The mines in Anderson county were the largest producers, followed by those of Campbell, Morgan, Marion, Claiborne, Grundy, Rhea and White. Each of these counties produced over 200,000 tons.

The number of coal miners employed in the State for the year 1898 was 7,820.

The amount of coke produced in Tennessee in 1898 was 394,545 tons, for which were consumed 722,356 short tons of coal. The yield of coke produced from a ton of coal was 54.6 per cent; when the coal is washed the yield is 60 per cent. There were 1,997 coke ovens in Tennessee during the same year. Coke was first employed in Tennessee for making iron at Rockwood, December 4, 1869.

418. Rapidity of Production.—The amount of coal mined in Tennessee in 1854 was only 8,836 tons. The production in 1873 was 350,000 tons, and ten years thereafter the production reached one million tons. For the year 1898 it was 3,022,896 tons. Taking periods of five years, since 1873, the output of coal has increased as follows: From 1873 to 1879, 28 per cent: from 1877 to 1885, 89 per cent; from 1882 to 1887, 123 per cent; from 1887 to 1892, 10 per cent; from 1892 to 1898 (6 years), 48 per cent. (The ton used in the above statistics is 2,000 pounds).

419. Brown Coal or Lignite.—Lignite (from the Latin for wood) is an impure, half-formed coal found in the more recent formations. In it the woody structure is not destroyed, and may be easily seen with the naked eye. It occupies a place midway between the true coal and a mass of dead vegetable matter. In appearance it sometimes looks like true coal, but has rarely the luster

and compactness of that mineral. Sometimes it is of a brown color, spongy and light.

Lignite does not take fire readily, but when ignited burns like rotten wood, and gives out the peculiar odor of burnt vegetable matter.

420. Extensive beds are found in the counties whose highlands overlook the Mississippi Bottoms, especially in Obion, Dyer, Lauderdale, Tipton, and Shelby. A bed has also been reported in Johnson county.

The seams often overlie each other, with beds of clay and sand interstratified, which correspond to the shales and sandstone of the coal measures. They vary in thickness from a few inches to four or five feet. These beds do not spread out very far, and appear to have been formed from accumulations of drift or from the former growth of swamps. Some varieties of lignite are hard, and when polished present a brilliant black surface. Such constitute the jet used in jewelry.

421. At Raleigh, in Shelby county, a mine of lignite was once opened and worked and the lignite used as a fuel, but it did not prove satisfactory. When used as such it must be mined in summer and thoroughly dried, and even then it is inferior to wood as a producer of heat and resembles peat.

422. The student should familiarize himself with this substance, its proper place in the formations, and its points of similarity and dissimilarity to true coal. It is often mistaken for genuine coal, and many fruitless adventures have resulted from ignorance in these particulars, and much valuable time and money lost in Tennessee.

CHAPTER XVII.

Iron Ores and Iron Manufactures.

423. Early History of Iron-making in Tennessee.—The making of iron early engaged the attention of the pioneers of Tennessee. Wherever they went they searched for iron ores. The first bloomery was built at Embreeville in 1790, another at Elizabethton in 1797. A furnace was built in Sullivan county in 1797 at the junction of the forks of the Holston. On Iron Fork of Barton's Creek, in Dickson county, the Cumberland furnace was built between 1790 and 1795. In 1856 there were 75 forges and bloomeries, 71 furnaces, and 4 rolling mills in the State of Tennessee. The capacity of the furnaces varied from 5 tons to 18 tons per day. The average capacity of the furnaces in the State at present is 100 tons each per day. Up to 1868 charcoal was the only fuel used in the blast furnaces of the State, but during that year Gen. J. T. Wilder sucessfully made iron with coke at Rockwood, in Roane county.

424. Iron Belts.—The iron ores of Tennessee occur in four well-defined belts which pass across the State.

1. The Eastern Iron Belt extends in a northeasterly and southwesterly direction and lies at the foot of the Unaka Range in East Tennessee.

2. The Rockwood or Dyestone Belt forms a border to the eastern foot of the Cumberland Table-land, but spreads out laterally from ten to twenty miles into the great Valley of East Tennessee and into the Sequatchee and Elk Fork Valleys.

3. The Cumberland Table-land has imbedded in the

shales of the coal measures a carbonate of iron in the form of nodules. This ore is of but little value in Tennessee. This belt coincides with the coal region.

4. The Western Iron Belt lies mainly in Middle Tennessee upon the Highland Rim west of the Central Basin, but embraces Benton and Decatur counties, in West Tennessee.

I. The Eastern Belt.

425. The Eastern Belt runs through the counties of Johnson, Sullivan, Carter, Washington, Unicoi, Greene, Cocke, Sevier, Blount, Monroe, McMinn, and Polk. The iron ores in this belt are of three kinds—viz., limonite, hematite, and magnetite. Each of these ores may be recognized by the color of the powder made in pulverizing them. Limonite makes a yellow powder; hematite, a red powder; and magnetite, a black powder.

426. Limonite or brown hematite is by far the most abundant of these ores. It has the same composition as iron rust. It is indeed a hydrous oxide of iron, and when pure contains 59.92 per cent of metallic iron, 14 per cent of water, and the remainder combined oxygen. This species of iron ore occurs in pockets in various forms known as pot ore, pipe ore, honeycomb ore, needle ore, yellow ochre, and compact ore.

427. In the Eastern Belt this ore occurs mostly in shapeless masses in the compact form. It is found most abundantly not in the high mountains but in the foothills and spurs and occasionally in the valleys and coves, mingled with clays and cherty masses. In Greene

county it is found associated with the oxide of manganese.

428. The hematite (bloodstone) is an anhydrous oxide of iron; that is to say, it is comparatively free from water. Though theoretically without water, it always contains from 1 to 4 per cent, and yields when pure about 70 per cent of metallic iron. There are two varieties of this ore: the dyestone or soft and the compact or hard. The dyestone ore is sufficiently soft to be easily crushed with a hammer. It is used in dyeing cloth, from which it took its name.

429. The hard red hematite is found in the valley of Stony Creek, in Carter county, in massive layers; in Sullivan county, in veinlike, nearly vertical masses; in Monroe and Cocke counties in compact masses; on Cross mountain in angular nodules; and in McMinn county, east of Athens, in nearly cubical masses. The latter body of ore is singular in the fact that it occurs in the Lower Silurian formation. The same character of ore outcrops in Loudon county.

430. Magnetite.—This ore takes its name from its magnetic properties. It is an oxide of iron of an iron-black color, granular in form usually, sometimes crystallized and always compact. It is the richest in metallic iron of all the iron ores, yielding when pure 72 per cent of metallic iron. It occurs in the older formations and shows a greater freedom from injurious ingredients than any other iron ore. By far the largest quantity of steel rails are made of this ore because of its purity. It is found in workable quantities in Tennessee only in the mountain spurs of Carter county that

run down into Crab Orchard Valley. Very large deposits occur at Cranberry, in Mitchell county, North Carolina, just beyond the Tennessee line.

II. The Rockwood Belt.

431. The Rockwood or Dyestone Belt lies in three or four lines, the most important being parallel with and at the eastern base of the Cumberland Table-land. The other lines are often the result of decapitated folds, and are interrupted by breaks or gaps. One of these lines lies on the eastern side of Sequatchee Valley at the western foot of Walden's ridge.

432. This red hematite is very variable in quality. When thoroughly leached it is soft and rich in metallic iron, yielding about 56 per cent. When hard the high percentage of limestone reduces its content of metallic iron. This ore is often called *fossil ore* or *fossiliferous red hematite* from the quantity of petrified remains found in it. These fossils are casts of crinoidal buttons, small corals, and fragments of trilobites. It is sometimes called *oölitic* ore because it abounds in small, flattened oölitic grains. In color it is sometimes a bright red, sometimes nearly scarlet, and sometimes of a royal purple. Some of it has the appearance of a specular ore having a highly splendent luster. This ore is regularly stratified like coal. The beds vary in thickness from a few inches to six feet or more.

433. The mining of this ore has been carried on for many years in the counties of Hamilton, Bradley, James, McMinn, Meigs, Rhea, Roane, Anderson, Camp-

bell, Union, Grainger, Claiborne, and Hancock east of the Cumberland Table-land, and in the counties of Marion, Sequatchee, and Bledsoe in Sequatchee Valley.

434. The layers of fossil or dyestone ore are associated with red and greenish shales and thin, even-bedded sandstones. These with the ore constitute the Rockwood formation of the Niagara geological series of the Upper Silurian age. In the ridges containing the dyestone ore are found, above it, the Black shale and the Tullahoma group. The ore occupies a horizon next under the Swan Creek phosphates as they occur in Middle Tennessee.

435. The Rockwood or Dyestone Belt offers great advantages for the economical manufacture of iron. In many places coal, ore, limestone for flux, and sandstone for furnace hearths are all found within a few hundred yards of one another and near transportation. The Dyestone ore occurs in its thickest beds near Birmingham, Ala., in proximity to good coking coal and limestone, and is the principal cause of the rapid growth and prosperity of that city. Chattanooga, Dayton, and Rockwood in Tennessee and Rising Fawn in Alabama enjoy, to a limited extent, the same advantages.

III. The Belt of the Cumberland Table-land.

436. The iron ores of the belt of the Cumberland Table-land have never been used in the manufacture of iron in Tennessee, though the same character of ores is largely used in Pennsylvania and Ohio. They are known as clay-iron stones. They occur in nodules and sometimes in layers, in greater or less quantities, throughout the area of the coal formation. These ores

rarely yield more than thirty per cent, usually not over twenty, of metallic iron. When roasted the percentage of iron is largely increased.

IV. The Western Iron Belt.

437. This belt is fifty miles wide, and runs through the State from north to south, embracing an area of 5,400 square miles. It also extends northward into Kentucky to the Ohio river, and southward into Alabama. The following counties are included in the Tennessee portion of the belt—viz., Lawrence, Wayne, Hardin, Lewis, Perry, Hickman, Humphreys, Dickson, Houston, Montgomery, and Stewart on the eastern side of the Tennessee river, and Benton and Decatur on the western side.

438. The different varieties of limonite are found in this belt, with some hematite, and red ore in the form of turgite, associated with the limonite. The ore usually occurs in the highlands, associated with cherty masses and gray and red clays. The lumps of ore are variable in size and are disposed in no regular order in the banks.

The main typical features of a bank may be thus noted:

439. 1. A covering of clay and chert and rounded gravel four or five inches in thickness, which constitutes the "stripping."

2. Below this covering a bed of clay, flint, and sand with ore.

3. The ore lying scattered at irregular intervals through this bed, sometimes in layers, with intermingled chert and clay, sometimes in "nests," and sometimes in large, irregularly

shaped masses, several feet in thickness; again in lumps from the size of a walnut down to a grain of corn.

4. The course of the ore is marked by tortuous dark veins or seams winding through the banks in different directions, and sometimes swelling out into rounded or shapeless masses of varying thickness. These are the principal characteristics of every bank.

440. The pot ore, so usual in these banks, are hollow concretions filled with water or decomposed chert.

The largest deposits now worked are those in Lawrence and Wayne counties.

A fine powdery ore, though sometimes compact, mostly hematite, occurs in several knobs not far from Clifton, in Wayne county, the only locality in the Western Belt where the red ore is found in quantity. There are a few counties on the eastern side of the Highland Rim containing considerable quantities of ore, Overton, White, Putnam, and Warren having the largest deposits.

441. Near Iron City, in Lawrence county, a stratified bed of mixed material, consisting of the carbonate of iron, limonite, and limestone, occurs, forming a separating layer between the Lower and Upper Silurian limestone. It is known as spathite, and has been mined to some extent.

442. For the year 1898 there were mined in the State of Tennessee 308,611 tons of limonite or brown ore, and 284,616 tons of hematite, making a total of 593,227 tons. Much of this ore was used in furnaces in other states. The number of furnaces in Tennessee during the same year was 23. Of these, 13 used coke and 10 used charcoal as fuel. The aggregate capacity of

these furnaces was 2,290 tons of pig iron in twenty-four hours. Of these furnaces, three are in the Eastern Iron Belt, nine are in the Dyestone Belt, and 11 are in the Western Iron Belt.

443. The following table represents the average analyses of the different kinds of iron ores found in the State after being dried:

	Hematite.	Limonite, E. Tenn.	Limonite, W. Iron Belt.	Magnetite.	Fossil Ore, Soft.
Sulphur..	0.164	0.119	0.070	0.115	0.110
Phosphorus	0.038	0.161	0.592	0.004	0.510
Water	1.060	10.530	11.120	0.490	0.960
Silica	6.110	3.81	6.220	5.290	10.970
Metallic iron	56.690	57.89	52.880	64.04	52.110

444. Iron ores are found in workable quantities in forty-four counties in Tennessee, as follows: Anderson, Benton, Bledsoe, Blount, Bradley, Campbell, Claiborne, Carter, Cocke, Decatur, Dickson, Greene, Hamblen, Hamilton, Hancock, Hardin, Houston, Humphreys, Hickman, James, Johnson, Knox, Lawrence, Lewis, Loudon, Marion, McMinn, Meigs, Montgomery, Monroe, Overton, Perry, Polk, Rhea, Roane, Sevier, Sequatchee, Stewart, Sullivan, Unicoi, Union, Washington, Wayne, and White.

THE MANUFACTURE OF IRON.

445. Iron is the king of metals. It is more useful to mankind than all other metals combined. From it are fashioned the implements of agriculture and the tools employed in the mechanic arts. The weapons and arms for national defense, the sheathing of the ships of war, the railway lines that transport persons and freight to all parts of the country, the electric wires that enable people living far apart to communicate with one another and that form the links that bind us to all nations, the magnetic compass that fixes the limits of our lands, and guides us with certainty and safety over fathomless oceans, are made possible by the useful properties of iron. The degree of civilization among the nations of the earth is measured by its use. Those that have made the greatest progress in the

arts and sciences, in elevation and intelligence, in the comforts and conveniences of civilized life, are those that use the greatest quantity of iron.

446. Iron products are divided into three general classes—viz., *cast*, or *pig iron; wrought*, *soft* or *hammered iron* and *steel.*

Cast or pig iron is the direct product of the blast furnace. It has a granular structure, is hard and readily broken, and its specific gravity is about 7.27. It may be melted at high heat and run into moulds. Our stoves, cooking utensils, plows, car wheels are the result of the fusible qualities of pig iron. It is not malleable—that is, it cannot be hammered into shape like wrought iron. The production of pig iron in the State of Tennessee in 1898 was 263,439 long tons. The largest production was in 1897, when it reached 272,130 long tons. Tennessee ranks sixth among the States of the Union as an iron-producing State.

447. The Smelting of Iron Ores.—To make cast or pig iron, certain proportions of iron ore, limestone, and fuel, either in the form of charcoal or coke, are used. When charcoal is used and the iron ores yield fifty per cent of metallic iron the proportions are about as follows: 800 lbs. of iron ore, 80 lbs. of limestone, 25 bushels of coal.

These ingredients are put in the furnace from the top, and the proportions named is called "a charge." Each charge will make from 350 to 400 pounds of pig iron. The heat required to melt the ores runs as high as 3,500 degrees Fahrenheit. When there is much siliceous matter in the iron ores more limestone will be required and the amount of pig iron will be proportionally reduced. The changes that take place in the furnace under the intense heat are about as follows; The limestone is quick-

ly converted into lime, which unites with the sand, clay, and other impurities of the ore, forming a fusible, impure glass. This, being lighter than the melted iron, floats on top and is drawn off as a *slag*. The white-hot charcoal takes the oxygen from the ore and sets the iron free, which, settling at the bottom of the furnace as a liquid mass, is drawn off into small gutters or channels made in sand. When cooled it is taken up and is called pig iron. The limestone is called a *flux*, because it melts with sand and clay into a *flowing* slag. The whole process is called *smelting*.

448. In the Birmingham (Alabama) district the usual charge, when soft red fossil ore is used carrying fifty per cent of metallic iron, is 3,000 lbs. of coke, 4,480 lbs. of iron ore, 2,240 lbs. of limestone.

449. The product from this charge is one ton of iron weighing 2,268 lbs. The absorption of carbon and the adherence of sand to the pig iron make the iron ton 28 lbs. heavier than the long ton. The richer the ores, the smaller the amount of limestone required, and this ingredient in the charge is regulated to suit the character of the ores. Some of the ores are nearly self-fluxing because of their large content of the carbonate of lime.

450. Wrought or Soft Iron.—This is most usually made of pig iron by remelting or stirring, or working it when so melted. The process is termed *puddling*. The object of puddling is to expose every portion of the mass to the flames of the furnace, so as to burn out the carbon. With the loss of carbon iron loses its fusibility, and becomes tough and malleable, It is also changed from a granular to a fibrous texture, and may be bent or twisted without breaking. When taken

from the furnace it is hammered or rolled into bars. During the process its specific gravity is increased from 7.27 to 7.78.

451. Wrought iron is also made directly from the ore by a single fusion in small forges called *Catalan* forges. The ore is pounded, mixed with charcoal, and subjected to a moderate heat.

These forges were for nearly a century used in Johnson, Carter, and Campbell counties. They made on an average about 300 pounds of bar iron each a day.

452. The presence of sulphur or phosphorus in wrought iron is exceedingly injurious. Phosphorus makes the metal *cold short*, or liable, when bent *cold*, to crack. *Red short*, due to the presence of sulphur, is the name given to iron which cracks at a welding heat.

453. Steel.—This is a compound of iron containing from .06 to 3 per cent of carbon, which is made fusible and malleable at high temperature. It has the malleable property of wrought iron and the fusible property of pig iron. Steel is the strongest compound of iron.

454. Formerly steel was made only by the cementation process, which was done by enveloping bar iron in powdered charcoal in a close crucible and keeping the whole at a high temperature for many days. By this process carbon was absorbed, and what was then known as "blister steel" was made. At present there are three principal kinds of steel made in the United States:

(1) Bessemer;
(2) Open-hearth;
(3) Crucible.

455. *Bessemer steel* is made by removing the carbon and silicon

in the pig iron, which is done by forcing atmospheric air through it while in a molten condition. After these two constituents have been removed, the proper proportion of carbon is added by the introduction of *ferro-manganese* or spiegel. No phosphorus is removed by the Bessemer process. The pig iron used in making it should not contain more than .08 to .1 per cent of phosphorus. The percentage of manganese in Bessemer iron will average about .5 per cent.

456. *Open-hearth steel* may be made from high phosphorus iron. The range of phosphorus may run from nothing to 3 per cent. All sorts of scrap iron or pig metal may be used. The process consists in fusing the pig iron by the introduction of air and gas through a reverberatory furnace. After the charge has been melted, lime and the oxide of iron are added for the purpose of removing the carbon, silicon, and phosphorus. The purifying agent in this process is the oxygen contained in the oxide of iron, which, combining with the phosphorus in the iron, forms phosphoric acid. This acid has a greater affinity for lime than it has for iron. It therefore leaves the iron, unites with the lime, and goes into slag. Oxygen also combines with carbon and forms carbonic gas, which escapes during the process. Oxygen likewise combines with the silicon, which forms silica. This has a greater affinity for lime than it has for iron, and so this injurious ingredient leaves the iron and goes out with the slag as a silicate of lime.

Ferro-manganese, after this purifying process, is added, by which the proper proportions of carbon and manganese are supplied. The amount of phosphorus in Bessemer steel is not diminished from the total amount held by the pig iron at the commencement of the Bessemer process. The open-hearth process is therefore superior to the Bessemer process in this, that the phosphorus may be reduced to any required limit.

Both the Bessemer and open-hearth processes are divided into the *acid* process and *basic* process. Irons high in silicon and

low in phosphorus are treated in the siliceous or acid converter. Irons high in phosphorus and low in silicon are treated in the basic converter. The acid converter has a siliceous lining; the basic converter has a lining of calcareous or limy material.

457. *Crucible* or *tool steel* may be made by either process, the only requirement being to have the contents of phosphorus low and that of carbon high. A small amount of crucible steel is made in Chattanooga.

458. Carbon is the hardening element in steel. *Dead, soft steel* carries only .06 per cent; steel for nails, .15 per cent; steel for boilers, .25 to .35 per cent with phosphorus as low as possible. *File steel* requires as high as 1.25 per cent of carbon.

459. *Steel rails* carry .4 to .5 per cent of carbon when made by the Bessemer process, but when made by the open-hearth process .6 to .7 per cent is not objectionable. In the latter process the amount of phosphorus may be reduced to a lower limit, and as the amount of phosphorus is decreased the amount of carbon may with safety be increased.

460. Uses. 1. *Bessemer steel* is more cheaply manufactured than the other kinds of steel, and is mainly used in the production of rails, structural material, plates, and sheets, cut nails, fish-plates, splice bars, railroad spikes, wire rods, and bars. It is also used in the manufacture of steel castings.

461. 2. *Open-hearth steel* is used largely in the manufacture of beams, girders, angles, and other structural material; plates, and sheets, wire rods, bars, railroad, and machinery castings; locomotive, car, and wagon

axles; agricultural implements, etc. Very little of it is used in the manufacture of steel rails. Almost, if not all, the armor plate now produced in this country is made of open-hearth steel. Very few cut nails, however, are made from steel produced by this process.

462. 3. *Crucible steel* is employed for making cutlery and tools, fine springs, castings, material for safes, jails, etc.; plates for saws, projectiles, razors, etc. It is much more costly in its manufacture than Bessemer or open-hearth steel, is much purer, and is therefore used chiefly in the manufacture of articles requiring keen edges, and great elasticity.

463. Tennessee and several other Southern States have immense bodies of ore suitable for making open-hearth steel and crucible steel, but a very small quantity adapted to the making of Bessemer steel.

464. The advantages that Tennessee offers for the manufacture of iron are:

(1) The ores are accessible and of good quality;

(2) The ores exist in great variety, and by mixing them properly almost any grade of iron may be made;

(3) The ores lie near limestone and coking coal, and in regions where heavy forests of timber abound for the making of charcoal;

(4) The mildness of the climate and the productiveness of the soil make the cost of living low, which cheapens labor;

(5) The low price of iron ore and coal properties, in consequence of which a smaller amount of capital is required in the original investment.

CHAPTER XVIII.

Other Useful Minerals.

465. Under this head we shall embrace the ores of copper, zinc, and lead; gold, iron pyrites, oxide of manganese, barite or barytes, copperas, alum, petroleum, salt, niter, epsomite, gypsum, and the mineral waters, all of which exist in greater or less quantities in the State.

I. Copper.

466. The Copper District.—Copper is one of the most valuable minerals of Tennessee. The copper-bearing district lies in Polk county and is confined to a mountain basin containing about forty square miles and elevated 1,800 feet above the sea. Hills and ridges characterize the surface of this basin, and it is rendered still more rugged by the presence of gneissoid rocks and metamorphic slates, that stand out prominently in the valleys and on the slopes and tops of the hills and ridges. The sterile aspect of the valley is further increased by its nakedness, most of the timber having been cut off for the manufacture of charcoal. The whole of the copper region lies in the metamorphic formation. The strata of the valley dip at a high angle toward the southeast.

467. Copper Veins.—The copper ores occur in three veins, which lie at considerable distances from one another. These veins of ore are plainly marked. The top of each vein is covered with an iron ore called *gossan*, from a German word for "cap."

468. Ores for Copper.—Beneath the gossan are found many varieties of copper ores, the principal ones being:

1. Black copper or tenorite; an *oxide of copper*, occurring in dull black masses and yielding from 60 to 70 per cent of metal. This, when the mines were first opened, was the most abundant ore.

2. Cuprite or the *red oxide of copper*, associated with the last and yielding about 89 per cent of copper. Its color is deep red, with various shades.

3. Malachite or *green carbonate of copper*, having a light copper-green color, yielding about 72 per cent of metal when pure. Some of it admits of a high polish and can be used in making jewelry and in ornamental work.

4. Azurite or *blue carbonate of copper*, of a deep blue color, yields 69 per cent of the oxide of copper.

5. Copper pyrite or chalcopyrite, a *sulphide of copper and iron*, having a brass-yellow color. It contains, when pure, 34.6 per cent of copper, 30.5 per cent of iron, and 34.9 of sulphur.

This ore resembles gold and iron pyrite. It is distinguished from gold by crumbling when cut, and from iron pyrite in yielding easily to the point of a knife, and in not striking fire with steel. This is now the most abundant copper ore worked at Ducktown, which is the name by which the copper region of Tennessee is known.

6. Native copper, occurring in branching, or as it is called *dendritic*, forms (from a Greek word signifying tree). But a small quantity of this exists.

7. Blue vitriol or chalcanthite is the *sulphate of cop-*

per. It has a sky-blue color and yields about 32 per cent of the oxide of copper. Many beautiful masses have been met with in the mines.

Several other ores of copper have been found to a limited extent, but have little practical value.

469. There are four or more companies at Ducktown, two of which are actively engaged in mining. These two companies make an output of about 120,000 tons of ore annually, which averages from 3½ to 4 per cent of metallic copper. Other companies have been organized, and the prospects are favorable for a much larger output of ore. Three furnaces are in operation at Ducktown, with a probability of several more being built in a short time. These furnaces reduce the ore to a *matte* yielding 50 per cent of metallic copper. In this condition it is shipped to refineries in the North, where it is converted into ingot copper.

470. History.—Copper was first discovered in Tennessee in 1843, but it was not mined until 1849. During the year 1855 there were shipped 14,291 tons of copper, worth at that time $1,000,000. Over 1,000,000 pounds of ingot copper were shipped from Ducktown between 1865 and 1869. After the comparative exhaustion of the black copper ores and the discovery of rich copper mines in the west the mining at Ducktown almost ceased for a few years.

The revival of the copper-mining industry was brought about by the building of the Marietta and North Georgia railroad in 1889. With this outlet to the coal mines of Tennessee, coke was substituted for charcoal in the smelting works; and, being less than one-half as expensive as the charcoal formerly employed, it reduced the cost of smelting the copper ores to a point that made the industry profitable.

II. Zinc.

471. Zinc is an important product of Tennessee. The most extensive deposits of zinc ores yet found in the State are at New Prospect in Union county, Straight Creek in Claiborne county, New Market and Mossy Creek in Jefferson county. In Union county there is a belt fifty or sixty feet wide in which two varieties of zinc ores appear to be abundant. This belt is easily traced by the absence of trees. The veins run vertically into the rocks and are from a few inches to several feet in thickness. These veins with the network of siliceous matter form the belt. The inclosing walls of the veins are shales and magnesian limestone of the Knox group.

The veins at Mossy Creek are irregular, but they occur in rocks of the same age as those in Union county. Throughout the entire distance of sixty miles from Mossy Creek to Loudon zinc ores in limited quantities are found. Zinc ores are also mined at Bluff City, in Sullivan county.

472. Ores of Zinc.—Three ores of zinc are found in Tennessee: Sphalerite or Zinc Blende, Smithsonite, and Calamine.

Sphalerite is a *sulphide of zinc.* It has a brownish yellow color with a resinous luster, and is very brittle. When pure it yields about 67 per cent of zinc and 33 of sulphur.

Smithsonite is a *carbonate of zinc*, of a white, gray, or light-brown color, sometimes green. It is easily broken, has a pearly luster, and will effervesce with

acids. It contains 64.54 per cent of the oxide of zinc and 35.46 carbonic acid.

Calamine is a *silicate of zinc*, of a whitish color, sometimes tinged with blue, green, or brown. It dissolves in heated sulphuric acid. It contains 67.4 per cent of the oxide of zinc, 25.1 silica, and 7.5 water.

473. These ores are all found associated more or less with galena, or the sulphide of lead. The two most important are the smithsonite and calamine. They occur in massive and in irregular veins in the dolomites of the Knox Group, and are sometimes incrusted on the rocks in stalactitic and mammillary forms. Zinc blende is also found in the same formation associated with galena.

474. The ores mined in Union and Claiborne counties are carried to Clinton, the county seat of Anderson county, where they are smelted and metallic zinc is produced. The ores yield about 45 per cent of metallic zinc and about 1 per cent of lead after being concentrated.

The oxide of zinc is made from the ores mined in the Mossy Creek district. This oxide is largely used for making white paint.

III. Lead.

475. Ores of Lead.—The ores of lead are not abundant in Tennessee. Galena and Cerussite, however, occur in small quantities and have been mined to a limited extent.

476. *Galena* is a *sulphide of lead*, and the most important ore of that metal. It is easily recognized by its leaden color and metallic luster. When pure it con-

tains 86.6 per cent of lead and 13.4 per cent of sulphur.

477. *Cerussite* is a *carbonate of lead*, and has the same composition as the white lead used in painting. It is usually stained a gray or brown color. It contains 83.46 per cent oxide of lead and 16.54 carbonic acid. It effervesces with nitric acid. An analysis of that found at Leadville, in Jefferson county, shows about 69 per cent of lead.

478. Almost every county in the eastern part of the State has deposits of galena. Like the zinc, with which it is associated, it is found in the strata of the Knox Dolomite. In Union county it presents itself in true veins, generally in grains and lumps. In Washington county, at Bompass cove, it is disseminated in grains through the mass of rock, with pyrite and zinc blende. At other places, as in McMinn county, it appears in irregular masses or bunches.

479. Veins are also found in Monroe, Bradley, and Jefferson counties, all of which have been worked to some extent. The one in Bradley county supplied some lead during the civil war. That in Jefferson county has been more recently worked. At this place both the carbonate and sulphide are met with. Many veins have been discovered in the Central Basin, one of some promise in Williamson county, but they have proved of no practical value. Some beautiful specimens have been picked up in Hickman, Henry, and other counties. There are three lead mines in Tennessee: two in Bradley county and one in Williamson county near Nolens-

ville. The output in the State rarely exceeds 2,000 pounds per annum.

IV. Gold, Iron Pyrite, Oxide of Manganese, Etc.

480. Gold.—On Coco creek, in Monroe county, mining for gold was carried on for many years. The total amount taken from that place and coined has not exceeded $170,000. The largest lump found was worth about $20. A gold-bearing quartz vein, found on a low ridge dividing the waters of Coco creek from those of Tellico river, has been worked. No active operations are now carried on.

481. Iron Pyrite or Pyrites.—A *sulphide of iron*, containing 46.7 of iron and 53.3 of sulphur. It has a golden yellow color and is often mistaken for gold, which it very much resembles; hence the popular name of "Fool's Gold."

It exists in every division of the State in small quantities. The best deposit now worked is in Carter county, on Stony creek, twelve miles northeast of Elizabethton, where 1,000 tons have recently been mined. It runs as high as 52 per cent of sulphur. Pyrite is found associated with the copper ores in Polk county, and occurs in beds in Carter and Greene counties. In Moore and Perry it forms considerable banks and is found associated generally with the Black shale and cretaceous strata. A bed has recently been found in Cheatham county.

482. Iron pyrite (*bisulphide of iron*) is in great demand for the manufacture of sulphuric acid, which is

employed in large quantities in Tennessee for the manufacture of fertilizers from the phosphate rock. A good deposit of pyrite in the State accessible by railway lines would be a great desideratum. The greater part of the material now used in making sulphuric acid is imported from foreign countries.

483. Sulphate of iron (*green vitriol or copperas*) as well as sulphur and alum, is made largely from iron pyrites.

484. The student should learn to distinguish iron pyrite or pyrites from gold. This may be done in several ways:

1. Gold is malleable and can be easily cut. Iron pyrite can neither be cut nor flattened by hammering.

2. Iron pyrite will strike fire with steel as readily as a flint; gold will not strike fire with anything.

3. Upon a whetstone a black mark can be made with iron pyrite; gold gives a golden yellow metallic mark.

4. If coarsely pulverized, and roasted in a shovel to a red heat, pyrite will burn; gold will remain unaffected.

There is another sulphide of iron, called magnetic pyrites, which occurs largely in the Ducktown region.

485. Oxide of Manganese.—This mineral is often associated with iron ore. It has an iron-black color, and makes an earthy black powder, by which it may be distinguished from hematite and limonite iron ores. From magnetic, which gives a similar powder, it may be distinguished by not acting on the needle of a compass.

486. Uses.—It is used in the arts for the manufacture of a bleaching material, and also for painting pottery and staining glass. Oxygen gas is also made from it.

When mixed with iron ores and reduced in the furnace it produces a peculiar kind of iron, called *speigeleisen* and *ferro-manganese.* In these forms it is largely used in the making of Bessemer and open-hearth steel. The oxide of manganese is mined in Carter county, near Elizabethton and in other counties in East Tennessee. The production in the State rarely reaches 2,000 tons per annum.

Like iron, it is found in small deposits all over the State; sometimes the specimens are beautifully crystallized.

487. Barite, Barytes, or Heavy Spar (*sulphate of barium*).—A whitish mineral, remarkable for its weight. It is often pulverized and mixed with white lead for making cheap paints. It is found in many localities in both East and Middle Tennessee. It usually occurs in veins associated with galena, and is one of the minerals forming the gangue, or enveloping material of that ore. When prices justify, it is mined in Bradley, Greene, Washington, and Jefferson counties. Considerable deposits are also met with in McMinn, Smith, and other counties. About 10,000 to 20,000 tons are mined annually.

488. Copperas, or Green Vitriol.—This is a *sulphate of iron*, usually derived from iron pyrite. The Black shale, when it is protected by overhanging rocks but exposed to the action of the atmosphere, crumbles and forms incrustations and deposits of impure copperas. This is due to the decomposition of the pyrite in the shale.

489. There are hundreds of such sheltered places, called

"rock houses," in which masses of copperas may be found naturally. One near Manchester, in Coffee county, is called Copperas Cave on this account.

Copperas was extensively manufactured, from 1861 to 1865, at the copper mines at Ducktown, from the refuse thrown out. This refuse consists in great part of iron pyrite. Copperas is employed in the manufacture of writing ink. It is also much used by dyers and tanners, and also in cities as a purifying, disinfecting agent.

490. Alum.—This well-known mineral is frequently found associated with copperas in the "rock houses" in Tennessee. It is formed by the decomposition of iron pyrite in contact with clay. It is largely employed for dyeing and medicinal purposes.

491. Petroleum is found in Morgan, Overton, Fentress, Pickett, White, Jackson, Dickson, and Hickman counties. Some of the wells sunk on Spring Creek, in Overton county, in 1865, were very productive. Recently several wells have been sunk in Pickett, Fentress, Morgan, and Putnam counties, of which about ten or twelve yielded oil, but only six are considered good producers. Two kinds of oil have been found: the black and the green. It is believed that oil may still be found in large quantities within the State. The present production reaches between fifteen and twenty thousand barrels per annum.

492. The Black shale, by distillation, can be made to yield oil. Some beds of this are so saturated with this oil as to burn awhile with a bright flame when thrown upon coals. For this reason it has often been mistaken for stone coal. It differs from

coal in not burning to ashes, the lumps remaining the same size, only the oil burning out. The richest shale yields from thirty to forty gallons of oil to the ton. It is not uncommon in Great Britain to get sixty or eighty gallons to the ton. The coal oil used in the United States is refined petroleum, and is more extensively employed than all other materials for illuminating purposes.

493. Salt.—Salt water has been found in Anderson, White, Van Buren, Warren, Overton, and Jackson counties. In Anderson and White counties salt has been made within a recent period. The wells of White county yielded for many years fifty bushels per day. No salt of consequence has been made in the State since 1865.

494. Nitre.—There are numerous caves in the limestone formations that supply a nitrous earth from which nitre, or saltpetre (*potassium nitrate*), can be made. Works were in active operation at many points during the war of 1812, and for a while during the civil war Nitre is one of the constituents of gunpowder, the others being sulphur and charcoal.

495. Epsom Salts, or Epsomite.—This mineral is found associated with alum and copperas.

496. Gypsum.—No beds of gypsum have been found in the State of sufficient extent to be of any economic value. Small crystals have been observed in the soil east of Bay's mountain. It is sometimes found in concretions of iron ore called pots, and also mixed with nodules of iron in the Western Iron Belt. It occurs in some of the lead veins. In some caves it takes the form of daz-

zling incrustations, often appearing as snowy rosettes, or icy vegetation. Beautiful specimens of *selenite*, or crystallized gypsum, have been found in Williamson and Cheatham counties.

497. Mineral Waters.—Tennessee abounds in mineral waters, embracing soda, chalybeate, sulphur, magnesian, and alum. Chalybeate springs break out from the lofty heights of the Unaka Range, as well as from the Cumberland Table-land. Along the base of the Clinch and Chilhowee mountains numerous springs of sulphur water take their rise, sometimes singly and sometimes in groups. The springs in Grainger county have a national reputation.

498. The counties of the Highland Rim are noted for the excellence and value of their sulphur waters. Those in Macon, Coffee, and Franklin counties are famed throughout the Union for their medicinal virtues. Henry and Hardin counties of the Plateau Slope have many springs and wells which supply sulphur water. From some of these wells it pours forth in great volumes, forced up by pressure. The sulphur well in Henry county yields 100 gallons a minute.

499. The Black shale is the most fruitful source of the sulphur waters all over the State. The alum waters of Hawkins, Grainger, Humphreys, and other counties also owe their origin to the same formation.

Many chalybeate springs are located in regions where the pure air, the magnificent scenery, cooling breezes, and other healthful influences make them favorite resorts for invalids and others seeking recreation.

CHAPTER XIX.

Rocks and Clays of Economic Value.

500. In this chapter we shall consider the limestones, marbles, granites, sandstones, hydraulic rock, lithographic stone, clays, fertilizing and glass material.

501. Limestones.—The most abundant of all the rocks in the State are the limestones. They are of every shade of color, running from a pearly gray through buff, yellow, dove-colored, red, brown, blue, to black. Some of these limestones are heavily bedded—that is, they occur in thick layers and are compact. Other varieties are laminated and sandy, and soon crumble down by exposure to the weather.

In Bedford county a flexible limestone occurs which works easily. Another variety resists the action of fire, and is called fire rock. Both are highly prized for building purposes.

Some limestones are excellent for making lime, and at many points on the railroads thousands of barrels are burned and shipped every year.

502. Marble.—This is a granular and crystalline limestone usually, but any limestone that will take a good polish, and will look well after it is polished, is termed a marble.

503. The marbles of Tennessee have acquired a richly deserved fame throughout the United States, on account

of their beautiful appearance and high polishing qualities. There are several varieties: the black, gray, magnesian, fawn-colored, red variegated, conglomerate, and breccia.

The black marble, sometimes beautifully streaked with white veins of calcite, is found in Washington, Greene, Sevier, Blount, and other counties in the eastern part of the State. It is easily worked, and makes quite a handsome appearance when polished. The black color is derived from the presence of organic matter.

The counties which have furnished the largest supplies of gray and variegated marbles are Hawkins and Knox, though many others (as Jefferson, Grainger, Union, Blount, Loudon, and McMinn) have large quantities of it. In Hawkins and Knox the marble lies in strips, sometimes many miles in length. It forms occasionally bold bluffs on the rivers.

504. The red variegated is prized for its pleasing appearance, and is used mainly in finishing and decorating the interior of buildings. When polished it shines with a glowing brilliancy, the reddish and whitish spots that appear on its surface giving it a delicacy and richness of tint that is very beautiful and attractive.

505. Brown and flesh-colored marbles are found in Jefferson and Hamblen counties. A fawn-colored marble occurs in Lawrence county, on the Highland Rim, capped by iron ore; and the gray and red variegated in Franklin, Lincoln, and other counties in the Central Basin. Coarser marbles are found in Hamilton, Benton, and Henry counties.

The magnesian marble occurs only in the Knox dolomite. It is too dull in color to be attractive; nevertheless it is considered a good building stone.

506. Some limestones are made up of rounded pebbles. When these are susceptible of a high polish they constitute the conglomerate marble. When the imbedded fragments are angular it is called breccia marble. Both conglomerate and breccia exist in the coves and valleys of the Unaka Range. Blount, Monroe, and McMinn counties supply the greatest abundance. In some of the conglomerate and breccia marbles the imbedded gravel varies in color. When polished these look like mosaic work. Some twenty-five large quarries of marble are in active operation in the State, and large quantities of the gray and red variegated are shipped North for ornamental purposes.

507. Tennessee ranks third among all the states in the value of the marbles produced, it being about $400,000 annually, which is about 20 per cent of the whole production of the United States. For interior decorations Tennessee marble stands far in the lead of that of any other State. It was first used for this purpose in the Capitol at Washington about 1844, and about 1852 it was used for interior decoration in the Capitol at Nashville, and shortly afterwards in the State Capitol of Ohio. After this the demand for it came from many states in the Union. For outside building material it was used by the government in the erection of the customhouses in Knoxville, Chattanooga, and Memphis. It finds a large and ready sale among the manufacturers of

furniture for making table-tops, etc., for which purpose it has supplanted the lighter-colored marbles.

508. As a building stone its merits have grown rapidly since an investigation made in 1895 by the University of Tennessee showed that its crushing strength averagéd about 16,000 pounds to the cubic inch. A testing-machine company of Philadelphia, demonstrated in May, 1895, that two-inch cubical blocks of Tennessee marble bore a crushing weight of between 59,250 and 68,850 pounds before they weee broken.

Tennessee marble will doubtless soon become as popular as a building stone as it has heretofore been as a material for interior decorations.

509. Onyx Marble.—This is found in some quantity in Anderson county.

510. Gneiss or Stratified Granite.—This is, ordinarily, a crystalline compound of quartz, feldspar, and mica. When hornblende is in the rock it is called *syenite.* The supply of this rock in Tennessee is very limited. Quarries could be opened at a few places in Johnson, Carter, and Washington counties, from which gray and flesh-colored granites might be procured. A compact, hard, greenish granite in which the epidote replaces hornblende, called *unakyte*, is found in Cocke county. It is very hard and resists well the erosion of water and the action of the atmosphere.

511. Sandstones.—These are abundant in every part of the State, and are much used for building purposes. Some, as the Clinch mountain and Chilhowee sandstones, are very hard and difficult to work; others are soft and

may be hewn with an ax. These softer sandstones are found above the St. Louis limestone, in the counties of the Highland Rim. A variety beautifully laminated is also found in the Bon Air Coal Measures. This sandstone is often nearly white and of good grain, making handsome structures. It is called a freestone, because it works easily under the hammer. Some of these sandstones of a bluish color make good whetstones.

512. Flagstones.—Sandstones occur often in thin sheets or layers suitable for making pavements and hearths. These are called *flagstones*, and abound in White, Bledsoe, and other counties of the Highland Rim, and also upon the Cumberland Table-land. They occur in layers of varying thickness. The iron limestones of East Tennessee are thin-bedded and make good flagstones.

513. Lafayette Sandstone.—A red, hard, ferruginous, conglomerated sandstone is found in isolated masses in West Tennessee, and serves a good purpose for making foundations to buildings. It belongs to the Lafayette formation formerly called the Orange Sand, and supplies a want in that portion of the State where building stones are very scarce. A notable outcrop of this occurs at Millstone, in Tipton county.

514. Saccharoidal Sandstone.—A saccharoidal sandstone of a dazzling white color is found in Benton county. It is quite hard and durable.

515. Hydraulic Rocks.—The best rocks for making hydraulic cement—that is, cement which will set under water and become hard—are impure carbonates of lime. The impurities consist of clay, silica, and often mag-

nesia. These cement rocks abound in Hardin, Wayne, White, Decatur, Warren, Montgomery, Knox, and McMinn counties. Several other counties furnish good quarries. Cement was long made in Hardin county, near Clifton, and was highly esteemed for plastering cisterns and making structures under water, as bridge piers. In Knox county cement is made of the brown calcareous shales.

516. Dolomite.—This is a magnesian limestone, and is mined to a considerable extent in Stewart county and in East Tennessee, and is used for making the basic lining of steel furnaces. It is quite abundant in the Valley of East Tennessee.

517. Roofing Slate.—In the Ocoee group are strata of a pale green, semi-talcose slate, from which good roofing material may be made. This slate, when free from pyrites, is very durable. It splits easily into thin plates with smooth surfaces. Polk, McMinn, Monroe, Sevier, Blount, and Cocke counties have an inexhaustible supply.

518. Millstone Grit.—Stones suitable for the grinding of grain exist in various counties. The quartzose gneiss in the metamorphic formation has been used for making millstones. Several localities in Johnson and Carter supply such rocks that answer well for grinding corn.

The masses of chert included in the strata of the Knox Dolomite have been found to make very excellent millstones. Some of it has a suitable cellular structure, especially where it has been exposed to the weather. Claiborne, Jefferson, and Knox counties abound in this rock. It is a true buhrstone. Immediately below the

Black shale formation occurs a rock at places which consists of a bed of shells closely compacted and silicified, giving it where exposed a surface filled with cavities. The millstones manufactured from this rock are thought to be equal to the French buhr. Trousdale and Coffee counties have the finest presentations of this material. Millstones, except for grinding corn in water mills, are rarely used in Tennessee.

519. Lithographic Stone.—Almost all the stone used by engravers in the United States for making maps and designs has been imported from Germany. Recently a bed of compact, grayish-colored limestone in Putnam county has been tried, and found to give excellent impressions. This stone is found near Allgood, a few miles east of Cookeville.

A fine compact stone of even texture, and conchoidal fracture, underlying the sandstone of the Cumberland Table-land, may be used for lithographic purposes.

Specimens from Overton, and Jefferson counties show all the characteristic features of the lithographic stone from Germany.

520. Clay for Fire Bricks.—Numerous deposits of fire clay are found in Stewart and Houston counties. The color of the clay is a grayish white. Bricks made from this clay were used in the rolling mills for many years. Good fire clay should contain little or no lime, magnesia, or iron.

The clays underlying some of the coal seams have been used in making fire bricks, as well as some of the grayish shales after being ground into a powder.

521. Potter's Clay.—Potter's clay has an unctuous feel and should be free from iron. Inferior pottery is made from a ferruginous clay in White county. The best clays in the State are of a whitish color, and occur in Hamilton, Hickman, Perry, Wayne, Montgomery, Houston, and in many of the counties of both East and West Tennessee; and especially in Carroll, Henry, and Benton.

522. Kaolin.—This results from the decomposition of feldspar and is found in small quantities in Carter county. This is the real *porcelain clay.* Some excellent porcelain clay is found in Carroll county. From this is made the best tableware.

523. Natural Fertilizers.—The green sand of the Cretaceous formation in Hardin, McNairy, and Henderson counties contain variable quantities of potash, which is one of the constituent elements of *glauconite* or green earth, a mineral of greenish color that is found disseminated among the masses of decomposed marine shells. Carbonate of lime is also a constituent of the shells. Phosphoric acid, a most powerful fertilizer, is also found in composition, and the value of the green sand depends in part upon this ingredient.

524. In some of the samples of green sand an analysis shows about 50 per cent of silica, 10 of potash, and phosphoric acid, and from 2 to 10 per cent of carbonate of lime, besides alumina and protoxide of iron. These fertilizing materials have been overshadowed by the rich and extensive deposits of phosphates described elsewhere.

525. Glass-Making Material.—Good sands for the manufacture of glass are found in the State. The glass in the State capitol was manufactured at Knoxville, from sand obtained on the opposite shore of the Holston river. Good sand is also found at Coal Creek, in Anderson county, near coal and limestone. The loosely compacted conglomerate or pudding stone found upon the Cumberland Table-land, when blasted, resolves itself into a bed of white sand and pebbles. The sand is separated, washed, exported, and used in the manufacture of the best plate glass. Some of it is shipped to Indiana for use in the glass works of that state.

CHAPTER XX.

Phosphates.

526. *Phosphate of lime*, or bone phosphate, is found in many counties in Middle Tennessee. The largest deposits are in Maury, Hickman, Lewis, Marshall, Perry, Williamson, Giles, Sumner, and Davidson counties, and may be looked for in all the counties of the Central Basin and in those places in the State where the Devonian Black shale is found, and immediately under this shale.

527. The amount mined in Tennessee for the year 1898 was 350,050 short tons. Of this, 326,588 tons were mined in the Mt. Pleasant district, and the remainder in the Centerville district, with the exception

of a small quantity mined in Perry county. The total amount mined in the State since its discovery in 1893 up to June 30, 1899, was 844,647 short tons.

528. The phosphates of Tennessee are of five different kinds and occupy different geological horizons.

1. The Capitol* or Mt. Pleasant phosphate (Maury, Davidson, and other counties).
2. The College Hill or Hudson phosphate (Sumner and Davidson counties).
3. The Swan Creek phosphate (blue rock), including that occasionally found in the Black shale (Hickman and Lewis counties).
4. The phosphate balls of the Maury Green shale.
5. The precipitated white phosphates of Perry county.

529. The Mt. Pleasant and Hudson phosphates belong to the Lower Silurian formation, and occur in the counties of Maury, Williamson, Giles, Marshall, Davidson, Sumner, and Hickman. The Capitol or Mt. Pleasant phosphates form the richest beds.

530. The Capitol or Mt. Pleasant phosphate occurs in what is known as the Capitol limestone bed, and has evidently been formed from that limestone by a process of leaching, leaving behind the phosphate of lime. The series of rocks at Nashville includes among others the following:

1. The Orthis bed, which is the lowest in this series.
2. The Capitol or phosphate limestone, 25 feet in thickness.

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*It is called *Capitol* because the unleached rock of this bed was used in building the Capitol at Nashville.

3. The Dove limestone, 11 feet in thickness.

4. A group of three unimportant beds, 45 feet in thickness.

5. The College or Hudson phosphate limestone, 120 feet in thickness.

The whole of this series, from the Orthis bed to the College limestone, both inclusive, embraces an average thickness in the Central Basin of about 160 feet, though often attaining 200 feet.

531. 1. In the Mt. Pleasant district, where the largest development of the Mt. Pleasant phosphate is found, the successive stages of the leaching process may be easily traced. The original rock was of a deep blue color, containing about 50 per cent of the phosphate of lime and 40 per cent of the carbonate of lime. The latter, being more soluble in rain water, was carried away, leaving behind a porous phosphate rock, having from 70 to 82 per cent of bone phosphate, or phosphate of lime.

532. The bottom of the beds of the Capitol or Mt. Pleasant phosphate is often interrupted by blocks of unleached rock called "*chimneys.*" Sometimes these chimneys are narrow vertical plates of the original rock separating thick masses of the phosphate; sometimes they appear as cones and again as wide flat bowlders rising up among the masses of phosphate. The deposit of phosphate is rarely less than three feet thick in the Mt. Pleasant district, often six feet, and occasionally ten to twelve feet.

533. Where the leaching is perfect the appearance of the phosphate is that of a loosely coherent, porous

rock disposed in thin, horizontal plates resting upon one another and forming altogether a thickness of several feet. It is soft and is mined without the use of explosives. An acre of phosphate six feet in thickness will yield about 3,000 tons. The perpendicular face of the deposits of phosphate exhibits a series of wavy lines, the result of the numerous exfoliations and local depressions.

534. The average analysis of twenty-three samples of the Capitol or Mt. Pleasant phosphate prepared for shipment shows the following:

Moisture	0.93
Phosphoric acid	36.27
Iron oxide and alumina	3.25
Bone phosphate on dry basis	79.06

Some of the harder rock shows 82 per cent of bone phosphate.

The estimated amount of phosphates in the Mt. Pleasant district is 20,000,000 tons, which underlie about 6,000 to 7,000 acres.

535. The Mt. Pleasant phosphate discovered in other counties of the Central Basin has not been thoroughly prospected, but appears to be lower in phosphoric acid. Some large beds may yet be found by a diligent search.

536. 2. The College or Hudson phosphate is found in Davidson, Sumner, Hickman, and other counties and is mined in the first two counties named to some extent. The thickness of this phosphate varies from a few inches to four or more feet. In quality it resembles the Mt. Pleasant or Capitol phosphate; and though not

covering such a large area as the Mt. Pleasant phosphate, it is much sought after and is regarded as quite valuable. Many hundreds of tons of it have been used in the manufacture of fertilizers with satisfactory results. It differs from the Capitol or Mt. Pleasant phosphate in the character of fossil shells which it contains and also in the fact that it occupies a higher level in the geological series. There are 50 or 60 feet of other strata between the Capitol limestone and the College limestone. This phosphate is considered an important addition to the Lower Silurian phosphates, and may be looked for wherever the College limestone appears. This College limestone, it may be added, is the highest of the rock beds in the vicinity of Nashville, and is the one upon which the University of Nashville is situated. It is called College for this reason. A very large deposit of this occurs in Sumner county north of Gallatin.

537. 3. Swan Creek or Devonian phosphates occupy a far wider area than the Lower Silurian phosphates. It is estimated that the stratum of the phosphate rock in Hickman and Lewis counties alone covers an area of not less than eighty square miles. Three varieties of the Swan Creek rock are found in this region—viz.:

(1) The Brown;
(2) The Gray } Blue Rock.
(3) The Blue }

538. The Brown rock of the Devonian age is found in the largest quantity on Indian Creek, in Hickman county, and appears to have resulted from the leaching

or weathering of the gray rock. Its thickness depends upon the amount of leaching that has taken place.

The hard phosphate rock of this age occurs in a seam varying from twenty to forty inches in thickness. There is locally a division in this seam. At the mines of the Duck River Phosphate Company the top member is gray in color, and 20 inches and over in thickness. Underlying the gray member is the blue or blue-black phosphate of equal thickness but more compact and harder to mine. The phosphates show by analyses to contain from 60 to 75 per cent of bone phosphate and less than 3 per cent of injurious ingredients in the form of iron and alumina.

539. In the application of the acids in making fertilizers the Swan Creek or "blue" phosphate, called in commercial circles "Blue Rock," is conceded to be the best rock yet found in the United States. Its finely powdered condition after being treated with acid and its quality of drying out quickly make it a great favorite with the manufacturers of fertilizers. The estimated quantity of this blue phosphate is over 100,000,000 tons.

540. 4. The phosphate balls of the Maury Green shales are found imbedded in a Green shale of the Devonian age. This variety shows by analysis about 60 per cent of bone phosphate. The expense of mining is too great at present to make this phosphate of commercial importance.

541. 5. Precipitated Phosphates. Geologists are not yet fully decided whether these phosphates belong to

the formation in which they are in contact or are a secondary formation, the material for which has been obtained by the solution of the blue phosphate and its subsequent precipitation. They have the form of *apatite* or crystallized phosphate of lime. These phosphates seem, for the most part, to be confined to Perry county, though specimens have been found in the Mt. Pleasant district. This variety is generally white, sometimes flesh-colored and often beautifully variegated. Its value is frequently impaired by a large admixture of chert. The best variety of this phosphate shows 85 per cent of the phosphate of lime and compares well with the other phosphates found in Tennessee.

542. History of Discovery.—The discovery of phosphate rock in stratified form in Middle Tennessee marks an epoch in the history of the development of the mineral resources of the State. Phosphates which were accumulated in the estuaries of South Carolina and Florida had been worked for many years, but they are different in quality and occur under very different conditions. In Tennessee the first beds were discovered in 1893, lying immediately below the Devonian Black shale in that part of Hickman county drained by Swan creek. This locality is about fifty miles southwest of Nashville. They are found on the same stream as far up as Lewis county. Perry county phosphates were discovered shortly afterwards.

In December, 1895, the heavy and valuable beds of phosphate were discovered in Maury county, near Mt. Pleasant. These latter deposits belong to the Lower Silurian age. They are richer, softer, and easier to mine than the Swan Creek phosphates.

543. Uses.—Phosphate of lime, bone phosphate, cal-

cium phosphate, or, as commonly called, phosphate, is largely used in every civilized country for the manufacture of commercial fertilizers. It is, indeed, the principal constituent in all such fertilizers. When ground and treated with sulphuric acid it is called acid phosphate or superphosphate of lime. Until the discovery of the phosphate beds in South Carolina, Florida, and Tennessee, bones were used very generally in the manufacture of superphosphates. With the superphosphate as a foundation, potash, nitrogen, and other fertilizing ingredients may be added so as to make fertilizers suited to the growing of various crops. Liquid acid phosphate is used as a medicine and as a refreshing beverage.

The discovery of these great beds of phosphate rock in Tennessee is destined to have a most salutary influence not only upon the agriculture of the State, but upon that of the whole country. A large amount of commercial fertilizer is now manufactured in Tennessee.

CHAPTER XXI.

Soils of Tennessee—Classification, Formation, and Productiveness.

544. Soil and Subsoil.—That portion of the earth's surface which can be cultivated, or which is usually stirred by agricultural implements, is called *soil*. The *subsoil* lies immediately under the soil proper, and is also sometimes stirred by deep culture.

545. All soils may be divided into two classes:

(1) Soils in place;
(2) Transported soils.

Soils in place are those derived from the disintegration or crumbling of the underlying rocks by mechanical and chemical agencies. Such soils partake of the character of the rocks from which they are derived.

Transported soils are those that have been formed from material transported by water or other means from its original position and redeposited. This material is so commingled as to give a widely varying character to all transported soils. Humus or decayed organic matter, whether animal or vegetable, is a factor in determining the value of a soil. Humus may be called digested plant food. Its effects upon the physical character of the soil are as important in determining its productiveness as the mineral constituents embraced in the soil. Humus gives friability and humidity and makes the soil permeable by the roots of plants.

546. Composition of Soils.—Soils consist of two parts, the *organic* and *inorganic*. The organic part is derived from vegetable and animal matter and may be burned away by heat.

The inorganic part remains after burning, and is composed of earthy and saline substances. The inorganic may be *soluble* or *insoluble* in water. The soluble portion consists of saline matter, and the insoluble of earthy material. The last varies from 70 to 95 per cent of the whole weight of the soils.

547. The principal ingredients of a soil are sand, clay,

lime, soda, potash, phosphoric acid, sulphuric acid, magnesia, and oxide of iron. The best test of the fertility of a soil is not the amount of mineral constituents contained in it, but the amount of such constituents that are soluble and may be assimilated by plants.

548. Hard rocks are changed into soil by the dynamic forces of heat, water, cold, and the roots of plants. The heat of the sun expands the rocks, the rain penetrates them, and the cold converts the inclosed moisture into little wedges, which shell off or disintegrate the thin outer crust. The hardest rocks cannot resist these forces, and in time are converted into a loose soil. The various acids, and mostly carbonic acid in rain water, assist in this process by dissolving the rocks. The action of these forces is called *weathering*.

549. The soils of the State may be classified as follows:

I. *Granitic.*—The soils of the main Unakas; rather sandy, micaceous, and mellow. Exclusively belonging to East Tennessee.

II. *Sandstone Soils.*—Generally sandy and poor.

III. *Siliceous or Flinty.*—Fine, sandy soil of the "barrens," or of the Tullahoma formation of the Highland Rim; generally much leached, with the original limestone matter dissolved out.

IV. *Yellow Loam.*—Soils of the Milan Loam; fertile; important. Exclusively in West Tennessee.

V. *Calcareo-Siliceous.*—Very fertile; important. Soils of the Loess; West Tennessee.

VI. *Calcareous Soils.*—The most important class of soils in the State; found in all divisions; derived from limestone rocks, or rocks containing lime; strong, durable, and suited to all crops.

VII. *Green Sand Soil* of the McNairy Shell bed. A calcareo-argillaceous mass underlying it, half consolidated into

rock, often called rotten limestone, which is loaded with shells of many varieties, among which large oyster shells are specially prominent.

VIII. *Shale Soils.*—Of varying fertility; stiffer than the generality of soils.

IX. *Alluvial* soils of river bottoms; black with humus.

550. The Granitic Soils.—These are confined exclusively to the counties traversed by the main Unaka Range, particularly to parts of Johnson, Carter, Unicoi, Cocke, Monroe, and Polk. Owing to the ruggedness of the surface where they prevail, these soils have not been fully tested for the production of field crops. At places the soil has a deep-black color, and is very friable. Buckwheat, pasture and meadow grasses, and potatoes grow well upon the mountain heights.

551. Sandstone Soils.—There are five varieties of sandstone soils, all more or less distinct:

(*a*) Chilhowee mountain soil;
(*b*) Knox sandstone soil;
(*c*) Clinch mountain sandstone soil;
(*d*) Dycstone soil;
(*e*) Soil of the Cumberland Table-land.

552. (*a*) The *Chilhowee sandstone* yields a soil of moderate fertility. Some areas are found that repay the labors of the husbandman in the production of potatoes, buckwheat, and garden vegetables. It also produces heavy forests of pine and chestnut, with thick copses of laurel, holly, and wild honeysuckle. Blue grass, too, in places covers the bald places with its verdant turf.

It is confined to mountain ridges in Johnson, Carter,

Unicoi, Cocke, Sevier, Blount, Monroe, and Polk counties. Of all the sandstone soils, it is probably the most productive. This productiveness, however, may be due to the extreme humidity of the climate where it prevails, as compared with other portions of the State. The soil is excellent for growing fine yellow tobacco. It contains 92.5 per cent of siliceous matter.

553. (*b*) The *Knox sandstone soil* is unimportant, being confined to long, narrow, sharp ridges of the Valley of East Tennessee, where the surface, by reason of its steepness, is unsuited for cultivation. It produces timber in limited quantities, but it is not well adapted to the grasses.

554. (*c*) *The Clinch Mountain Sandstone Soil.*—This occurs mainly on the southeast side of Clinch mountain, which traverses Grainger, Hancock, and Hawkins counties. It is found on Powell's mountain, which lies in Claiborne and Hancock counties; on Lone mountain, a continuation of the latter in the counties of Anderson and Union; and on some of the ridges of the Bay's mountain group, which lie mostly in Hawkins county. It is thin, sandy, and poor, sparsely timbered, and has immediately underlying it large sheets of sandstone. It has a pale yellowish color, and is almost entirely destitute of plant food. It is probably the most unproductive soil in the State.

555. It may be mentioned as a singular fact that the north west faces of these mountains has a calcareous soil, exceedingly fertile and highly productive. It is curious to observe the exuberance of vegetable growth on the one side, and the poverty

on the other. Stately trees with leafy tops, covered with vines and creepers, making an impervious thicket, characterize the northwestern side of the mountain, while the southeastern is covered with a hard shield of sandstone and a stunted growth.

556. (*d*) **The Dyestone Soil.**—This results from the weathering of the greenish calcareous shales and fine sand of the Dyestone or Rockwood group, and is found on the east side of White Oak mountain in James and Bradley counties, and on the slopes of the smaller Dyestone ridges. The rocks of this group are more varied in chemical composition than those of the other sandstone soils, and as a result there is more vitality in the soils. This is manifested in the better growth of timber, though owing to the ruggedness of the country very small areas have been brought into cultivation. Its agricultural importance is very limited.

557. (*e*) **The Soil of the Cumberland Table-land.**—This is the most important of the sandstone soils, inasmuch as the mountain is flat-topped and it extends over an area of about 5,000 square miles. This soil is usually sandy, porous, and infertile, and rests upon a coarse, ferruginous sandstone. Nevertheless at the foot of some of the knobs and ridges, and in some of the depressions that occur upon the mountain top, there are areas of moderate fertility.

The defects of this soil are porosity and a want of calcareous matter. Yet, notwithstanding its porous nature, there are many small swampy places in which the soil is of a dark-blue color, sometimes nearly black. The subsoil of these places is a blue clay, and

almost impervious to water. These swampy spots or swales are usually covered with a coarse, rank grass, and spotted with beds of fern, which form a thick mat. Such places abound in half-decomposed vegetable matter; and if drained and exposed to the correcting influences of the atmosphere, they soon become productive.

558. The best soils of this division have a yellowish red subsoil, with a thin coat of vegetable mold on the surface. Though thin, the soils are easily cultivated. The greatest agricultural value of this portion of the State is to be found in the abundance of wild, nutrituous grasses that cover the surface during the summer months, affording a rich pasturage. Apples and grapes yield plenteously. The soil is also well adapted to the growth of garden vegetables, and especially Irish potatoes. Chemical analysis shows that it contains about 77 per cent of insoluble matter, .4 per cent of potash, 2.3 per cent of ferric oxide, .6 per cent of alumina, .16 per cent of soda, and a very small per cent of lime and phosphoric acid.

559. Siliceous or Flinty Soil.—This is derived from the crumbling of the cherty masses belonging to the Tullahoma formation, and prevails in most of the counties of the Highland Rim. It is the soil of the "barrens." Wherever the subsoil is so porous as to permit the calcareous matter to be leached out, the surface soil becomes hungry, thin, and barren. But when the underclay is of a red color, unctuous and tenacious, the soil rivals the best in the State in productiveness and grows in great abundance the staple products.

560. Both kinds of soil, the leached and unleached, are

found associated on the Highland Rim, and rest upon beds of chert mingled with clay. The unleached is more properly called a calcareous soil. The siliceous soil of the "barrens" or Tullahoma formation, often whitish in color, produces coarse, rank grasses, which when young and tender are highly relished by cattle. It has recently come into favorable notice for the good quality of a certain kind of tobacco which it produces.

561. The soil of the "barrens" has about 87 per cent of insoluble matter. It is deficient in lime, phosphoric acid, and potash, as well as in drainage. The unleached or calcareous soils associated with the siliceous or barren soils are treated under the head of calcareous soils. No soils in the State respond more quickly to fertilizers than the white soils, but fertilizers do not last long.

562. Yellow Loam.—This embraces the soils of the Milan Loam, the varieties of mellow upland and highland soils that occur so generally in West Tennessee. They are based, not on solid rock, like the sandstone soils mentioned, but upon unconsolidated strata of matter mainly loamy, but sometimes sandy.

563. It does not follow because a soil is "sandy" that it is poor. The clay and calcareous matter that some contain give them a degree of body and vitality, which make them, for many crops, highly valuable lands. The way they lie, too, is an important consideration. If high, plateau-like, or gently rolling and well drained, such lands are often highly esteemed by the farmer; when, if steep or very hilly, they are not prized. In the latter case the soils have the same components, but un-

der tillage are easily washed and soon become comparatively worthless. The best cotton lands have these sandy soils. A typical sandy soil of West Tennessee shows about 89 per cent of insoluble matter; but the content of potash, magnesia, and phosphoric acid is far in excess of that of the barren soils last mentioned.

564. Calcareo-siliceous.—This soil occupies the eastern parts of Obion, Dyer, Lauderdale, Tipton, and Shelby. It is the soil of the Loess formation, which presents an ashen aspect in color and consistence, and contains more calcareous matter than the other unconsolidated formations of West Tennessee, with the single exception of the Green Sand soil of the McNairy formation. It is not unusual to meet, imbedded in the Loess, concretions of carbonate of lime. At some points they may be gathered by the bushel. The soil is similar in character to the formation—calcareous, siliceous, fine-grained, ashen, and sometimes slightly reddish or black. Its lands are among the most fertile in the State. The soil owes its good qualities not to its chemical composition alone but also to its fine powdery condition. Tobacco, cotton, wheat, oats, clover, and the grasses grow luxuriantly upon it, while the native growth of timber at one time was unsurpassed. This soil contains 79 per cent of insoluble matter. It also contains six times as much phosphoric acid and twice as much potash and lime as the siliceous soils of the "barrens."

565. Calcareous Soils.—These soils owe their fertility to the large amount of calcareous matter which they contain. They rest upon the different varieties of lime-

stone found in the State, and differ mainly in having a greater or less quantity of siliceous material or clay in their composition, making them friable or stiff, as one or the other ingredient predominates.

566. In durability, productiveness, and extent they surpass all other soils in the State, with the exception probably of the alluvial. They constitute the wheat, tobacco, blue grass, and much of the cotton lands of the State, and are found in all the minor valleys of the Valley of East Tennessee, in the Central Basin, on much of the Highland Rim, and in the Western Valley. But few of them occur in West Tennessee. These soils are classified according to the character of the prevailing limestone, and form the best farming areas. They cover in the aggregate one-fourth of the surface of the State. The calcareous soils of the Highland Rim in the tobacco districts of Robertson and Montgomery counties show about 78 per cent of insoluble matter, .39 per cent of potash, .078 per cent of phosphoric acid, 2.9 per cent of ferric oxide, .278 per cent of lime, and 4.4 per cent of alumina. The calcareous soils of the best part of the Central Basin show 76 per cent of siliceous matter, .41 per cent of potash, .158 per cent phosphoric acid, 2.096 per cent of ferric acid, .51 per cent of lime, and 4.28 per cent of alumina.

567. Green Sand Soil of the McNairy Formation.—This soil is of a kind of siliceous loam, resting upon an interesting formation in West Tennessee, which is, in the main, sand and clay intermixed, having as charactistic ingredients a considerable amount of carbonate of

lime, and numerous green grains called glauconite. The formation from which this soil is derived is loaded with shells. These supply the soil with fertile ingredients, and make it friable and productive. It is well adapted to the growth of cotton and corn, and some portions to the growth of wheat. This soil is confined almost entirely to the eastern part of McNairy and Henderson counties, and belongs to the Cretaceous formations.

568. Shale Soil.—As a top formation shale is rare. In a few of the narrow valleys of East Tennessee, the Black shale forms the basis of the soil. Such a soil is cold, clayey, unimportant, and unproductive except for the grasses.

569. Alluvial Soil.—This, altogether, occupies a large area in the State—nine hundred square miles of alluvial soil is on the Mississippi river. It is also the soil of the bottoms of the Tennessee and Cumberland rivers and of all their tributaries. The whole State is furrowed by rivers, creeks, and rills, each of which has lying upon its margin more or less alluvial soil. Some of the highland counties, as Perry, are alternate ridges and valleys. The alluvial soils differ greatly in character, color, aptitudes, and productive capacity, depending in part upon the formations of the surrounding highlands and upon the frequency or infrequency of the overflows. Where the water courses flow through or over limestone formations the sediment which they deposit is highly calcareous. When the streams gather their waters from gravelly hills or sandstone ridges the soil is deficient in carbonate of lime, and usually is not so productive. The

character of alluvial soil is generally determined by the region through which the stream flows.

570. On many of the streams are terraces, elevated above the stream beds and not subject to overflow, which often have the characteristic features of the low alluvial soils. These fluviatile deposits are exceedingly rich in plant food, and make our most generous soils. Their perfect drainage and freedom from overflows make them very desirable. For the growth of wheat they are especially adapted.

571. These constitute the principal varieties of soil in the State, but they often overlap and run into one another, giving an infinite variety, making soils warm or cold, light or heavy, loamy, marly, hungry, leachy, sweet, sour, clayey, marshy, compact, tenacious, fine, coarse, gravelly, and rocky.

572. The productiveness of a soil does not depend altogether upon its constituent elements, such as lime, potash, soda, phosphoric and sulphuric acids, and vegetable matter, but upon the rainfall, surface exposure, subsoil, drainage, degree of pulverization, and culture. Drainage is especially important.

573. Standing water is destructive of most of the field crops. On the other hand, the soil must not be so porous as to permit the fertilizer to filter to a depth beyond the reach of plants. For the purpose of production the best condition of soil is to be thoroughly pulverized and well drained of its surplus water, yet with an underclay that will catch and hold all fertilizing ingredients. The capacity of the soil for holding heat and

moisture has much to do with its productive energies. Calcareous sands, such as abound in the Central Basin, will absorb 100 units of heat, while argillaceous soils will absorb only 68. This power to absorb heat assures the growth and hastens the maturity of vegetable life. It also very perceptibly modifies the climate. Where there are whitish argillaceous soils, as on the Highland Rim, the air quickly becomes cool at nightfall. On the other hand, the prolonged radiation from the calcareous soils of the Central Basin often makes the nights uncomfortably hot.

QUESTIONS.

[The figures refer to the paragraphs, and not to the pages.]

INTRODUCTION.

1. What is the object of geology? What do we learn from its study?

2. What habits are formed by the study of geology?

3. What will be considered first in the study of this work? What should we know about the State? After a general view, what can we next study?

4. What will be the second step in the study of this work?

5. What will be the third inquiry? What do we mean by a stratum? A formation? What constitutes the foundation of geological science?

6. What does economic geology treat of? In the study of geology, where should we begin?

7. What will be the result of work of this sort?

PART I.

CHAPTER I.

Of what does Part I. treat?

8. What is the form of the State of Tennessee? How long and how wide is it? What would be the length of a railroad connecting the sharp diagonal corners of the State? What is the area of the State? How many square miles are covered by water?

9. What about the surface map of the State? How many other States touch Tennessee?

10. How does the State of Tennessee lie lengthwise? Between what? What is the elevation above the sea of its eastern border? Of its western? What does this indicate? What valley lies at the foot of the eastern mountains? How does the general surface of the State descend from the Valley of East Tennessee? What bar-

rier interposes? What is the average direction of the drainage of the State?

11. Give some account of the river system of Tennessee? Which are the largest streams? How many miles of navigable water does the Tennessee river furnish? For what is the Cumberland river remarkable? How many miles of navigable water are in Tennessee?

12. What has the eastern portion of the State been called, and why? What will the student find as stretching from Vermont to Alabama? What are these mountains called?

13. What are the special names of these mountains? What about the valleys lying between the mountains?

14. What is one of the best examples of these valleys? What is the width of the Valley of East Tennessee?

CHAPTER II.

Of what does this chapter treat?

15. How many natural divisions are there in the State? Give their names.

16. How many civil or political divisions? Give their names.

17. How many counties are there in the State? How many in East Tennessee? Name county seats.

18. How many in Middle Tennessee? Name county seats.

19. How many in West Tennessee? Name county seats.

CHAPTER III.

Of what does this chapter treat?

20. Give a description of the Unaka Range.

21. Where is its highest crest? Give the area of the portion lying in Tennessee?

22. Is the Unaka Range a single ridge? If not, what is it? How many of these parallel ridges are there? What is meant by "axis?"

23. Give some account of the Chilhowee Range.

24. What is said about the included valleys and coves?

25. How are these mountains cut by rivers? Tell something of this remarkable feature.

26. What are the "balds?" What is said of the grasses, farms, etc.? What about these places as summer resorts? Tell about the rain storms in the mountains.

27. Describe the views from the tops of the mountains.

28. Describe the Valley of East Tennessee. How is it bounded? What city occupies its center? What is the area of this valley?

29. What is its average elevation above the sea? Its elevation on the Virginia line? At Knoxville? On the Georgia line?

30. How does the Valley of East Tennessee appear when seen from the mountain tops? But in crossing it what do we find?

31. Give some account of the ridges of the valley.

32. How are the ridges grouped? Give examples of each kind.

33. Tell about the minor valleys and coves.

34. In what direction do the creeks of the valleys flow?

35. Describe Sequatchee Valley.

36. What rocks of the valleys and coves have an agricultural value?

37. Describe the Cumberland Table-land. What mineral abounds in this division? What is its height, and how many square miles does it embrace? Tell about its eastern and western edges.

38. What about its surface?

39. Describe its soil.

CHAPTER IV.

Of what does this chapter treat?

40. Give some account of the Highland Rim or Rimlands. How far does it extend? What does it encircle? What is its height above the sea? What is its area?

41. How is the surface? What is the effect of the streams? For what is the soil adapted? Where are the iron ore banks found?

42. What is the fifth division of the State, and why is it the most important?

43. Describe this Basin. What three rivers pass through it? What is the greatest length of the Basin, and what is its area? What is its depth below the rim?

44. How does it resemble the bed of a drained lake? How deep would this lake be in Nashville, if the Basin were filled with water?

45. What is the most valuable mineral found in this division of the State, and in what counties is it found?

46. Give a description of the Western Valley. What about the soil? What is its area? Its elevation above the sea?

47. Describe the seventh natural division of the State. Why is this division like new land to a traveller?

48. What of its plateau character? Its shape? To what distance does the Plateau extend west?

49. How is this division supplied with rivers? What is the area of this division?

50. Describe the last and eighth natural division.

51. What is its area? Its elevation?

Name all the natural divisions in order, beginning at the eastern part of the State.

CHAPTER V.

Of what does this chapter treat?

52. What regulates climate and what modifies it?

53. What covers great mountain heights in tropical climates? What elevation is equivalent to one degree of latitude?

54. What does climate regulate, and why?

55. What is the mean annual temperature of Tennessee? Give the average monthly temperature. What is the mean temperature for the winter months? For the spring months? For the summer months? For the fall months?

56. What is the absolute average range of temperature?

57. What are the number of days in which the temperature averages fifty degrees and above? What is said about the climate of Tennessee for persons working outdoors?

58. Give the mean annual temperature for the different natural divisions of the State on a line running east and west through the center. What does the difference amount to? What does the mean annual temperature of the Unaka Range correspond with? What does that of the Mississippi bottoms correspond with?

59. Give the annual temperature of Tennessee as compared with other countries? What are isotherms? Do the lines of equal heat correspond with the lines of latitude? Do they indicate equality of climate? How do the seasons in Tennessee differ from those of European countries?

60. Does the mean summer temperature of the several divisions of the State differ more than the winter mean temperatures? What are the means? What is the summer heat of the Unaka Range? What of the Valley of East Tennessee, the Table-land, and the other divisions of the State? How high does summer temperature reach? What is the greatest degree of cold observed in Tennessee, and at what dates? When does the coolest and warmest weather occur?

61. What about winter temperature and ice? What is the limit of domestic ice houses? What is the maximum thickness of ice found in Tennessee?

62. What about the frosts of Tennessee? What are the average intervals in the different divisions between killing frosts?

63. What is the average number of clear days in a year? Monthly average? Fair or partly cloudy days? Cloudy days? What does this show?

64. When are the most destructive frosts? How much longer is the period between killing frosts in the southern part of the State than in the northern? What effect does this have on agriculture?

65. What do you understand by precipitation? What is the average annual precipitation on the globe? What is it in the Torrid Zone? In the Temperate Zone? In the Frigid Zone? What is the rainfall of Tennessee sufficient for? What is the average annual precipitation in Tennessee, and how is it distributed? What is the monthly average for the spring months? For the summer months? For the fall months? For the winter months? What effect does this distribution have upon the growing and gathering season for crops?

66. Give the periods mentioned in the table of the greatest and least rainfall. Of the greatest and least annual temperature.

67. Give the average depth of snow for Tennessee. What about the snow of 1840? At what other dates did heavy snows fall in Tennessee?

68. Why is Tennessee especially desirable as a home?

69. What about the winds of Tennessee? What winds come charged with warmth and moisture from the Gulf of Mexico? What are their effects? What does the upper system of winds embrace?

70. What has been established in relation to the winds of Tennessee? What does this do for Tennessee?

71. For what is Tennessee remarkable? Give some of the varied features of Tennessee. How does it resemble the other States which adjoin it?

PART II.

CHAPTER VI.

72. What superficial covering has the earth?

73. What makes up the solid earth?

74. What is it to study geology? What does the word "geology" mean?

75. What does geology explain? In what sense is every stratum like a leaf in a book?

76. What is economic geology?

CHAPTER VII.

77. Of what do rocks consist? What minerals enter into the composition of Tennessee rocks?

78. What are ores?

79. What is an important characteristic of minerals? By what are the degrees of the hardness of minerals determined?

80. What of quartz or flint in determining hardness? How many members are there in the Scale of Hardness?

81. Name the first and last minerals in the Scale of Hardness.

82. What is a most common ingredient of rocks? What are some of the characteristics of quartz?

83. What are the three groups of the varieties of quartz? What is said of the crystals of quartz? What of geodes, and what do they frequently contain?

84. For what are the Hot Springs of Arkansas noted? What is amethyst?

85. What are included under waxy quartz? What are concretions? For what are some of the varieties of waxy quartz used?

86. What is chalcedony and what are some of its varieties?

87. What is flint? Chert?

88. How does jaspery quartz differ from the glassy and waxy kinds?

89. How does opal differ from quartz?

90. In what does silica differ from quartz?

91. A silicate is a compound of what?

92. Mention some crystallized native glasses.

93. How does quartz rock often occur?

94. Of what are beds of sand and sandstone made up?

95. What is the relation of calcite to limestone? How does calcite otherwise occur?

96. What is meant by the term "calcareous?"

97. What form can be split from crystals or calcite? *Ans.* A rhombohedral form.

98. What is Iceland spar?

99. What is the chemical composition of calcite?

100. What is the acid test for calcite?

101. How is hard or limestone water formed?

102. How are caves in a limestone region formed?

103. What is a stalactite? A stalagmite?

104. What is travertine?

105. How does dolomite differ from calcite?

106. What of the occurrence of dolomite rock in Tennessee?

107. What is the characteristic mineral of phosphate rock? How is massive apatite distinguished from ordinary phosphate rock?

108. Where, in Tennessee, does massive apatite occur?

109. How may phosphate rocks be distinguished from limestone?

110. What is the composition of apatite and phosphate rock?

111. What important rock does feldspar help to form? In what division of the State is that rock found? Give the chemical name for feldspar.

112. How may feldspar be distinguished from quartz?

113. What is cleavage?

114. From what minerals do the clays come?

115. What are the fire clays? How are clays formed? What is kaolin?

116. What are common clays? How may mica be recognized? Into the formation of what rock does it enter? For what is mica used and why?

118. Mention some of the characteristics of mica.

119. Describe amphibole and pyroxene. What is asbestos?

120. By what other name is amphibole known? Where does amphibole occur, and how may it be distinguished from mica?

121. What is sahlite? Augite?

122. Describe garnet, and tell how it occurs.

123. How does tourmaline occur, and in what does it differ from the other silicates?

124. What is the hardness of talc? Mention some of its characteristics; its chemical composition.

125. What is steatite, and for what is it chiefly used?

126. How does chlorite differ from talc? Into the formation of what rocks do talc and chlorite enter?

127. How does serpentine differ from talc? What is verd-antique marble?

128. Describe topaz.

129. What is sapphire? Alumina?

130. What names are applied to the various crystals of alumina? What is corundum? Emery?

131. What is diamond? Name the three forms of carbon. For what is graphite used?

132. Tell what you know of gypsum? What is selenite?

133. How does gypsum sometimes occur? What is alabaster?

134. Describe fluorite.

CHAPTER VIII.

What is the subject of this chapter?

135. What was the process of rock formation?

136. Is this process still carried on?

137. What of the hardening of West Tennessee strata?

138. How is it that rocks may contain a variety of mineral matter?

139. Name the three general classes of rocks.

140. What are some of the terms applied to sedimentary rocks?

141. What does metamorphic mean? What is said of the action of heat on sedimentary rocks? What are metamorphic rocks?

142. What is said of igneous rocks? What are *dikes?*

143. Tell what you know of sandstone and its varieties.

144. What are quartzites?

145. Define the following: Conglomerate, or pudding stone; breccia; siliceous conglomerate; calcareous conglomerate; ferruginous rock.

146. What is the characteristic constituent of limestones? How may limestones differ?

147. Name the common varieties of limestone.

148. What are *fire rocks?*

149. To what class do the limestones of this State belong?

150. How does the limestone of stalactites differ from ordinary limestone?

151. What rock does dolomite resemble?

152. What is the *dyestone ore* of Tennessee? What other iron ores are found in this State?

153. What are *shales?* Do shales differ from slates?

154. Describe shale further.

155. Describe a *bituminous shale.*

156. What are *alum shales?*

157. Tell what you know of slates.

158. Describe clay slate or argillite. How does its splitting differ from that of shales? What are sometimes found in argillite?

159. What is a *schist?* What is *mica schist?*

160. What is *mica slate?*

161. What is *hydro-mica slate?*

162. What is said of granite? What is its composition? Describe granite further.

163. What is syenite?

164. What is unakite?

165. How does gneiss differ from granite? In what mountain do we find gneiss and gneissoid rocks?

166. What mineral sometimes replaces mica in gneiss, mica schist, and mica slate? What are the resulting rocks called?

167. What is protogine?

168. When is granite called an igneous rock?

169. What are trap rocks? What is a trap? What is its composition?

170. Name some of the occurrences of trap in this country and in Tennessee?

171. What are the following: Dolerite? Basalt? Diorite? Amygdaloid?

172. What is porphyry?

173. How were lavas formed?

174. Name some of the ordinary lavas?

CHAPTER IX.

What is the subject of this chapter?

175. How are rocks classified according to their form? How does our classification on page 58 differ from this?

176. What is said of the rocks of Tennessee? Where may layers be observed?

177. What is illustrated in Fig. 8?

178. What is a *section?*

179. Name a region presenting remarkable sections.

180. Where in Tennessee may good sections be observed? What have rivers to do with sections?

181. What position do strata often assume? What parts of Tennessee have horizontal strata?

182. What is meant by a *jointed structure?*

183. What is said of the extent of strata?

184. What example is given? Describe the extent of the Black or Chattanooga Shale?

185. Account for the horizontal position of strata?

186. What is said of the raising of the strata out of the ocean? What of the wrinkling of the strata? What effects were produced by this action?

187. By what are the folds of a strata illustrated?

188. What is said of the bending of strata?

189. What does Fig. 10 illustrate? What is said of Sequatchee Valley?

190. What does Fig. 11 represent?

191. Define the following: Axis, anticlinal axis, synclinal axis, synclinal valley, decapitated fold.

192. What is an *outcrop?*

193. What is meant by *dip?*

194. What is meant by strike?

195. Traveling from West to East, where do we first meet folded strata of Tennessee rocks?

196. In what part of Tennessee are folded strata frequent? What is the direction of their dip?

197. What is Fig. 17 intended to illustrate?

198. How does Fig. 17 illustrate denudation in East Tennessee?

199. How have faults been formed? Point out the places of faults in Fig. 17.

200. What does the geologist observe as to sequences of strata in crossing a fault?

201. What is said of faults in East Tennessee?

202. What do Figs. 13 and 14 illustrate?

203. What is said of unstratified rocks?

204. How are veins made?

205. What is said of veins in Tennessee?

206. What about the denudation of strata? How has the elevated matter been carried away?

207. What about the denudation of strata at Knoxville? At Chattanooga?

208. What are other examples of denudation?

209. Of what is Sequatchee Valley an example?

210. How was this valley formed?

211. What does Fig. 20 illustrate?

212. What rocks yield most readily to wear and denudation?

213. What are valley-making rocks? What are ridge and mountain-making rocks?

214. Why do the valleys and ridges of East Tennessee run in a northeasterly and southwesterly direction?

215. How are table-lands formed? What of the Cumberland Table-land?

216. What of the outlines of the Central Basin?

217. When are strata said to be unconformable?

218. What does Fig. 22 illustrate?

CHAPTER X.

What does this chapter treat of?

219. What are imbedded in the rocks?

220. What are said of the rocks about Nashville?

221. What are fossils?

222. What is said of the fossils in a formation? What of the fossils at Nashville and McMinnville?

223. What illustration of the use of fossils is given?

224. What is paleontology?

225. What is necessary for the student to know?

226. Into what two great groups are animals divided? What are vertebrates? Invertebrates?

227. How many subkingdoms in all? What does the table on pages 89 and 90 give? What are the examples of animals of the simplest organization? Of the highest organization? What are the subkingdoms of the invertebrates? Describe them. What subkingdom is included under the vertebrates? What five classes of vertebrates are there? Name and define them.

228. What are rhizopods?

229. What animals were once included under the radiates?

230. What is said of crinoids? What of the abundance of crinoids in the ancient seas? Describe the form of a sea urchin.

231. What are bryozoans?

232. What are brachiopods?

233. The mollusks include what divisions? What are cephalopods? Gasteropods? What does *acephal* mean? Name some of the acephals. How do acephals differ from brachiopods?

234. What is stated in this paragraph?

235. How are the arthropods divided? What is said of trilobites?

236. Describe ostracoids.

237. What is barnacle?

238. What do the selachians include, and what is said of them?

239. What of the ganoids?

240. Into what two great groups are plants divided? Define the cryptogams. Define the phenogams. Into what three classes are the flowerless plants or cryptogams divided? Describe the thallogens. Describe the anogens. Describe the acrogens. What do the endogens include? What do the exogens include? Into what two orders are the exogens divided? What is said of the cycads? The conifers? The angiosperms?

241. What was the first condition of the earth, according to geologists?

242. What of the water from artesian wells? What other facts go to show the heated condition of the earth?

243. What is said of the formation of the crust of the earth? What of the ocean and stratified rocks?

244. What was the character of the first strata?

245. What of dry land and the creation of plants and animals?

246. What is said in this paragraph?

247. What is stated as the present condition of the interior of the earth?

248. What about the thickness of the crust of the globe? What is the rate of increase of temperature as one descends in the earth?

PART III.

What is the subject of this part?

CHAPTER XI.

What is the subject of this chapter?

249. In the Table of Formations, how is past time divided? How are eras divided? How are periods divided? What use is made of the word "age?"

250. How is the word "formation" used in this book?

251. What column gives, with two exceptions, the individual or primary formations of the State? What are the exceptions?

252. What subdivisions do the periods severally include? What does the cretaceous period include?

253. What do the eras severally include? What does Azoic mean? Eozoic? Paleozoic? Mesozoic? Cenozoic?

254. What does the map show? The names of the periods are given with what exceptions?

255. What great areas of rocks are shown on the map?

256. Compare this map with that on page 8. What is the extent of the section, and what does it serve to show?

257. What are the *mountain* divisions? And why so called? What eras are now to be considered? And under these what great division is first considered?

258. What is said of the rocks of this division? What of the areas of them in Tennessee?

259. In how many areas do the *Crystallines* occur in Tennessee? Where do they severally lie?

260. What does the division of Crystallines include?

261. What is said of the Azoic? What dikes cut them?

262. What is said of the second division, or subdivision, of the Crystallines?

263. What are the economic products of the Crystallines?

264. What of the rocks of the Ocoee? Thickness? Where seen? Of what mountain belt and ranges are they the chief rocks?

265. What do these rocks supply?

266. How many subdivisions of the Ocoee are given? What is the third era? And what period under it?

267. What is the thickness of the Chilhowee sandstone? What of its rocks? Where are they well seen?

268. Chilhowee Mountain is a type of what? What other mountains lie with it in a chain from Virginia to Georgia?

269. What do the strata of the Chilhowee yield?

270. How many divisions of the Chilhowee? Enumerate them.

271. What are the formations of the Knox group? With a single exception, to what part of the State do they belong? What is the exception?

272. What of the rocks of the Knox sandstone? What is a characteristic topographical feature? Name examples of ridges. What of iron ore beds?

273. What is said of the rocks of the Knox shale? What of its topography and agriculture? What towns are located in Knox shale valleys? What does Fig. 29 illustrate?

274. What is said of the Knox dolomite? How is it divided? What of it in the eastern valley? What further of its rocks? Its thickness?

275. What of its ridges in regions of tilted strata? What are examples of such ridges?

276. What do the slopes of the Knox ridges often supply? What do the regions of horizontal strata supply? What does the formation afford?

277. What does the section in Fig. 30 illustrate? Name the formations shown in the sections. Name the ridges.

278. What are some other Knox dolomite ridges and ranges? What towns are severally located on them?

279. Where does the Well's Creek Basin lie? Give its form and area. To what is its existence due? What is exposed here?

280. How do other formations outcrop in this basin?

CHAPTER XII.

Of what period does this chapter treat?

281. In what parts of Tennessee are Lower Silurian rocks greatly developed?

282. What is the thickness of the upper (or Lower Silurian) part of the Knox dolomite?

283. What two divisions of the Lower Silurian rocks, above the Knox dolomite, are seen in going from the East to the West? How does the shale change in going to the west side of the valley? What of the westerly extension of the group?

284. What is stated in this paragraph?

285. For what part of the State do we first consider the subdivisions of the Lower Silurian? Why do the strata in East Tennessee outcrop in long northeasterly and southwesterly lines?

286. (For the subdivisions of the Lower Silurian in East Tennessee see also Table of Formations.) What is the first subdivision mentioned? Of what kind of rock is it composed? What further is stated?

287. What of its occurrence in Jefferson county? In what does it abound? What towns are located upon it?

288. What is said of the Knoxville marble? What of its fossils?

289. What is said of the Sevier shale? Its thickness and changes?

290. To what do its hard, sandy layers give rise?

291. Enumerate the belts and areas of the Gray Knobs.

292. What is the first interpolated bed of the Sevier shale? Describe this group. What does Fig. 32 illustrate? What of the Red Knobs, and what line of them is mentioned?

293. What is the second interpolated bed, and for what is it noted?

294. What is the third interpolated bed? Describe the formation.

295. Where do the interpolated beds have their greatest development?

296. What divisions and subdivisions does the section mentioned in this paragraph show?

297. What makes the floor of the Central Basin? What the slopes of the bounding hills?

298. What are the three main subdivisions of the Lower Silurian in Middle Tennessee? *Ans.* Stone's River, Nashville, and Hudson.

299. Name and describe the first subdivisions of the Stone's River epoch.

16

300. Name and describe the second subdivision.

301. Name and describe the third subdivision.

302. Name and describe the rocks of the fourth subdivision. What towns are located upon the Lebanon limestone? What is the characteristic formation of the red-cedar glades of Middle Tennessee?

303. What is the second main subdivision of the Lower Silurian in Middle Tennessee?

304. Name the first subdivision of the Nashville epoch and describe its rocks. What towns are located upon it? What do its rocks supply?

305. Name and describe the second subdivision. Mention places where it may be observed. At what place does it supply hydraulic cement?

306. To what is this rock a guide? By what fossil may this rock be recognized?

307. What is the third subdivision? What rock was used in building the State capitol? What is the character of the rock? What of its laminated character?

308. What gives great interest to the Capitol limestone? How has the phosphate been separated from the formation? What point is a center of production for this phosphate?

309. Describe the occurrence of the Capitol limestone in the Central Basin. To what do many of the best lands of the Central Basin owe their richness?

310 to 313. Enumerate the remaining beds of the Nashville epoch.

314. What is the third main subdivision of the Lower Silurian in Middle Tennessee? What rocks are referred in this subdivision, and what does it include? Where, at Nashville, are its rocks found?

315. What is the most interesting feature of this subdivision? Where has its phosphate been mined?

316. How high, geologically, is the Hudson phosphate above the Mt. Pleasant? What does Fig. 33 show?

317. What are the economic products of the Lower Silurian rocks in this State?

318. How many members has the Upper Silurian in Tennessee, and what aggregate thickness does it reach? What of the outcrops of the Upper Silurian rocks in Middle and West Tennessee?

319. Describe the Clinch red shales.

320. Describe the Clinch sandstone.

321. Describe the White Oak Mountain sandstone.

322. What rocks are included in the Rockwood formation? The thickness? What do its highly ferruginous beds weather into? By what other names is the iron ore known? What is the greatest thickness of the ore?

323. What three formations constitute the "Dyestone ridges" of East Tennesse, and where do these ridges lie?

324. From what does the Clifton limestone get its name? In what divisions of the State is it found, and what is said of its thickness?

325. What is the formation of the "glades" in Hardin, Wayne, Decatur, and Perry counties? What does the formation exhibit at points along the Tennessee River? What do Figs. 34 and 35 illustrate? What, Fig. 36? What of the building material of the Clifton limestone?

326. What is the rock of the Linden limestone? Thickness? Where may good sections of this formation be seen? What does Fig. 37 represent?

327. What are the economic products of the Upper Silurian?

CHAPTER XIII.

328. What is said of the Devonian rocks in Tennessee? They consist of how many members? Whence comes the name *Devonian?*

329. To what is the name *Camden Chert* given? Whence the name Camden? What the thickness? Name some localities where it may be seen?

330. How are the three remaining members of the Devonian related?

331. Describe the Hardin sandstone. Where conspicuous? Thickness? Why chiefly interesting?

332. What is said of the Swan Creek phosphate? Thickness?

333. Describe the phosphate in its several varieties. How are the white, variegated, banded masses, like those of Perry county, formed?

334. Like what does the Swan Creek phosphate occur? And how is it mined? How does it differ from the Mt. Pleasant and Hudson phosphates?

335. What is the Black shale? What of its extensive occurrence?

336. Along the bases of what mountains does it outcrop? What of it in the Central Basin? What of its thickness?

337. Why is the Black shale mistaken for stone coal? What has been distilled from it? Why is it a source of sulphur water?

338. It is a guide to the Swan Creek phosphate for what reason?

339. What is there just before the Black shale?

340. What economic products from the Tennessee Devonian? What are the two subdivisions of the Carboniferous period?

341. What is the first epoch under the Subcarboniferous? What does it rest upon, and what is its character?

342. For what is the Green shale interesting? What are these concretions? How do they occur in the green shale? What percentum of calcium phosphate do they contain?

343. What is the heading of this paragraph? How many horizons of available phosphate are there in Middle Tennessee? What other occurrence is mentioned?

344. Name the different phosphates.

345. What formation lies next above the Maury green shale? What is said of the rocks of the Tullahoma formation? What of their occurrence in Tennessee? What does the formation include in East Tennessee? In West Tennessee?

346. What is said of the thickness of the series? What is its most common rock? What rock is left in regions where the strata have been leached?

347. Whence the name Tullahoma? What may be observed about that town? What county seats are located on the Tullahoma formation?

348. Why is the St. Louis limestone so called? What is the surface or cap formations of the Highland Rim? What changes do we see in going from the Central Basin outward across the Highland Rim?

349. What wide belt of country lying at the western base of the Table-land is based on the St. Louis limestone, and what towns does it include? What other large sections based on this limestone are mentioned, and what towns are respectively located on them?

350. Wherever this formation underlies the surface, what is it common to see? For what else are such regions remarkable?

351. What does Fig. 38 illustrate? What of iron ore banks resting on the Tullahoma limestone?

352. What division, forming the base of the Cumberland Tableland, follows next above the St. Louis limestone? Through what limestone is the tunnel of the Nashville & Chattanooga Railroad cut? What of the thickness of the mountain limestone?

353. What does Fig. 39 illustrate?

354. What rock makes the base of Lookout Mountain? What other occurrences of mountain limestone are there? What is said of a great fault in the formations near Montvale Springs?

355. What economic products does the Subcarboniferous supply?

CHAPTER XIV.

356. What are the Coal measures? Of what do they form the top or cap? What is their extent?

357. The section presented gives a good idea of what? The lowest beds outcrop just above what limestone? How many coals, or coal horizons, are included?

358. Where is the greatest thickness of Coal measures in Tennessee? Where does the Brushy Mountain coal field lie? A drill driven down vertically from one of the highest peaks to the limestone would penetrate what, and for what distance?

359. What are the three divisions of the Coal measures? How are they severally characterized?

360. What is said of the Bon Air measures? By what name is the topmost stratum known, and why?

361. Why are the Bon Air measures so called? What is the thickness? How many seams of coal, or coal horizons, do they contain? What counties mentioned contain valuable beds of coal belonging to these measures? Where else do we find these lower coals?

362. What further as to their occurrence?

363. What is said of the Bon Air measures?

364. What is the name of the second division of the coal measures? Why named Tracy City? The thickness of the series? And found in what? How many coals, or coal horizons, does the division contain? What is said as to their being workable?

365. What is the most important coal bed in the Tracy City measures? What its extent? In what counties mined? Where else occurring?

366. How does the area of the Tracy City measures compare with that of the Bon Air? Both divisions run under what?

367. What does Fig. 40 represent?

368. What is the third division of the Tennessee coal measures? It is a vast body of what? How many coal horizons does it include? How many beds of workable thickness? In what property are all contained?

369. What is said of the topography of the Brushy Mountain

measures? How high are the ridges above their bases? How high above the sea?

370. How are the coal resources of the Brushy Mountains above water level supplemented?

371. Where are all the coal horizons in Tennessee represented?

372. What economic products do the Coal measures yield? What towns are located on the Coal measures?

CHAPTER XV.

373. What is the subject of this chapter? To what part of the State are these eras confined? What is said of their strata?

374. What is said of the extension of the Gulf of Mexico? What of the "Old Shore?"

What is the fourth era? What period is now considered?

375. To what belt of country are the cretaceous formations confined? Name the formations and characterize each briefly.

376. Describe the Coffee sand.

377. Where are the layers of the Coffee sand exposed?

378. Describe the McNairy shell-bed. Describe the green grains found in it.

379. What do Figs. 41 and 42 represent? What is the thickness of the McNairy formation?

380. What is said of the Ripley formation?

What is the fifth era? What period is next considered?

381. What is said of the strata included in the Eocene period? What of their extent in West Tennessee? What are the two divisions of the Eocene period?

382. What is said of the Middleton formation? What special beds does it include? What is said of the bed of laminated or shaly clay, its extent, and the towns located upon it?

383. Where do beds of the La Grange formation outcrop?

384. What is the general character of these beds?

385. What is said of the artesian borings in this formation at Memphis? The depth of the wells and the thickness and character of the beds?

386. What, in this formation, are of economic importance?

387. What are represented in Fig. 43?

What period is next discussed?

388. Describe the Lafayette formation, its beds, and its occurrence.

389. What does it include? What does it yield?

What period is now considered?

390. What are the divisions of this period?

391. Name and describe the first division.

392. What is its extent, and what rich lands does it include? What is its thickness?

393. What are represented in Figs. 44 and 45?

394. What is Milan loam? What is its thickness, and what does it cover?

What period is next discussed?

395. What does the alluvium include? Where are its most extensive areas, and what is said of Lake county?

PART IV.

What is the subject of Part IV.?

396. Of what does economic geology treat?

CHAPTER XVI.

What is the subject of this chapter?

397. How is coal classed? What is the most important mineral of Tennessee? In what great coal field is that of Tennessee embraced? Give the direction and length of the Appalachian coal field. What is its productive coal area?

398. What is the number of square miles in the coal field of Tennessee? What counties does it include? What do the edges of the coal field in Tennessee resemble?

399. What are the divisions of the Coal measures of Tennessee?

400. In what counties is the Bon Air division seen? In what, the Tracy City? In what, the Brushy Mountain?

401. What is meant by Coal measures? Of what are they composed?

402. Give some additional facts concerning the Bon Air coal measures.

403. What do the Sewanee measures make?

404. How thick are the Brushy Mountain measures?

405. Are there any disturbances in the eastern edge of the coal field?

406. What advantage results from the deep ravines in the coal field?

407. What about the main conglomerate rock in Anderson and Claiborne counties?

408. How much coal will a bed one foot in thickness make to

the square mile? Estimated thus, how much coal has Tennessee? How long will it last at the present rate of consumption?

409. What are the two great varieties of coal known to commerce? Tell something of the qualities of bituminous coal.

410. What about anthracite coal?

411. To what variety does Tennessee coal belong? How are bituminous coals classified?

412. Define coking coal.

413. What is a non-coking coal?

414. Describe cannel coal.

415. What is the most valuable constituent in coal? What is the average analysis of Tennessee coals?

416. What substances are most injurious to coal?

417. How many coal mines were there in Tennessee in 1898? What was the annual production of coal? How many mines in each county? How much coke was produced the same year? What percentage of coke did the coal yield?

418. Give some facts showing how rapidly coal-mining has developed in Tennessee.

419. What is brown coal or lignite? Does it burn readily?

420. Where does it occur in Tennessee, and how does it occur? What is jet?

421. What about the mining of this coal in Shelby county?

422. Why should the student familiarize himself with this substance?

CHAPTER XVII.

What is the subject of this chapter?

423. Give some account of the early history of iron-making in Tennessee.

424. How many iron belts are there in Tennessee? Name them.

425. What counties does the Eastern Iron Belt pass through? What classes of ore are found? How do you distinguish each of these ores?

426. What variety of ore is most abundant in the Eastern Belt? How much metallic iron does limonite contain? How much water? How much combined oxygen?

427. In what situations is this ore found?

428. Give some idea about hematite ore, How many varieties are there?

429. In what situation is the hard red hematite found?

430. Give some idea about magnetite, its richness, and where found.

431. How does the Rockwood or Dyestone ore occur?

432. When thoroughly leached, how much metallic iron does the Dyestone ore contain? What other name is given to it, and why?

433. In what counties is this ore mined?

434. With what is the Dyestone ore associated? What constitute the Rockwood formation?

435. Give the reasons why this ore offers great advantages in the manufacture of iron.

436. Tell something about the iron ores of the Cumberland Table-land.

437. Describe the Western Iron Belt and its extent.

438. What other kinds of iron ore are found in the Western Iron Belt?

439. Describe the typical features of an iron ore bank in the Western Iron Belt? In what counties are the largest deposits now worked?

440. What about the red ore in Wayne County? What counties on the Eastern side of the Highland Rim have iron ores?

441. What class of iron ore is found near Iron City, in Lawrence County?

442. How much iron ore was mined in the State of Tennessee in 1898? How many furnaces were in the State during the same year? How many used coke and how many used charcoal? What was the aggregate capacity of these furnaces?

443. What iron ore in the table shows the greatest quantity of metallic iron? Which shows the least amount of sulphur and phosphorus?

444. How many counties in Tennessee contain iron ores in workable quantities?

445. How does iron rate as to its usefulness in comparison with other metals?

446. How are the products of iron divided? What is cast or pig iron? Describe some of its properties.

447. Tell how iron ores are smelted and what is put in a furnace when iron is made.

448. What is the charge when the dyestone ore and coke are used?

449. What is the product from such a charge? How many pounds in a ton of pig iron, and why is the ton greater?

450. Tell something about wrought or soft iron.

451. Is wrought iron ever made directly from the ore?

452. What effect does the presence of sulphur and phosphorus have upon iron?

453. Define steel.

454. How many kinds of steel are now made in the United States?

455. Tell how Bessemer steel is made.

456. How is open-hearth steel made?

457. How is crucible steel made?

458. What is the hardening property in steel? Define the difference between dead soft steel and steel for making nails, boilers, etc.

459. How much carbon do steel rails carry, made by the Bessemer process? Why may more carbon be carried when made by the open-hearth process?

460. For what is Bessemer steel mainly used?

461. What is open-hearth steel mainly employed for?

462. What are the special uses of crucible steel?

463. For the making of what kind of steel are the iron ores of Tennessee adapted?

464. What advantages does Tennessee offer for the making of iron?

CHAPTER XVIII.

What is the subject of this chapter?

465. What minerals will be embraced under this head?

466. Where does the copper-bearing district of Tennessee lie? Describe it. What formation is it in?

467. In how many veins are the copper ores found? What mineral caps the copper veins?

468. Name the different ores of copper. Describe black copper or tenorite. Describe cuprite, malachite, azurite, and copper pyrite, or chalcopyrite. What does the latter resemble? Describe native copper and blue vitriol.

469. Name the different ores of copper. Describe black copper. What is the present production of copper in Tennessee? How many furnaces are in operation?

470. Give some account of the history of copper-mining in Tennessee.

471. Where are zinc ores found in Tennessee? Give a description of the veins in Union county, at Mossy Creek.

472. How many ores of zinc are found in Tennessee? Describe sphalerite, Smithsonite, and calamine.

473. With what other ore are these zinc ores associated? Which are the most important of the zinc ores? How do they occur?

474. Where are the ores from Union and Claiborne counties smelted? What yield of metallic zinc do they make? What is made at Mossy Creek from the zinc ore found at that place?

475. Are the ores of lead abundant in Tennessee? What two ores of lead occur?

476. What is galena, and, when pure, how much lead does it contain?

477. What is cerussite? Describe it.

478. Are lead ores largely distributed in the eastern part of the State? In what strata are these ores found? How is it found in Washington county?

479. In what other counties are lead veins found? What two ores are found in Jefferson County? What about lead ores in the Central Basin? How many lead mines have recently been worked in Tennessee, and at what points? What is the output of these mines?

480. Where is gold found in Tennessee, and what has been the extent of mining?

481. What is iron pyrite? Describe it. What is its popular name? In what part of the State is it found?

482. For what is iron pyrite in demand?

483. What products are made from iron pyrite besides sulphuric acid?

484. How is iron pyrite distinguished from gold? What other sulphide of iron is found in the Ducktown region?

485. Tell about the oxide of manganese.

486. What are its uses? What is spiegeleisen?

487. What is barite or barytes? With what ore is it associated?

488. What is copperas, or green vitriol? And from what is it derived?

489. Where are masses of copperas found naturally? At what point was copperas extensively made from 1861 to 1865? For what purposes is copperas employed?

490. With what is alum found associated? How is it formed?

491. Where is petroleum found in Tennessee? Give some account of its production in the past and at present.

492. What amount of petroleum may be obtained from the distillation of Black shale?

493. What about salt in Tennessee?

494. Where is niter or saltpeter found, and for what is it used?

495. Where are Epsom salts found?

496. What about the occurrence of gypsum in Tennessee? What is selenite and where found?

497. Give some account of the different mineral waters in Tennessee.

498. What counties are most noted for mineral waters?

499. From what source came the sulphur waters? What is said of the chalybeate springs?

CHAPTER XIX.

What is the subject of this chapter?

500. Give the names of the substances treated of.

501. Describe the various limestones.

502. What is marble?

503. What is said of the marbles of Tennessee? What counties have furnished the largest quantity of marble?

504. For what is the red variegated marble prized?

505. Where are brown and flesh-colored marbles found? A fawn-colored? In what part of the Central Basin is marble found? In what counties of West Tennessee? Where is magnesian marble found?

506. What is conglomerate marble? What is breccia marble? In what counties are they found?

507. How does Tennessee rank in the production of marble? What is its annual value? For what purpose does Tennessee marble stand at the head? Where was it first used?

508. As a building stone, how does it stand? What is its average crushing strength? How much crushing weight did a cubical block of two inches stand?

509. Where is onyx marble found in Tennessee?

510. What is said of gneiss or stratified granite?

511. What is said of the sandstones of Tennessee?

512. What is said of the flagstones, and where do they occur?

513. Describe the Lafayette sandstone, and in what division of the State does it occur?

514. What is said of the saccharoidal sandstone?

515. What are hydraulic rocks, and where are they found?

516. What is dolomite and for what is it used and where found?

517. What is said about roofing slates in Tennessee?

518. In what counties does millstone grit occur?

519. What is said about lithographic stone? In what places is it found?

520. Where are good deposits of fire clay found in Tennessee?

521. What is said of potters' clay?

522. Where is kaolin or porcelain clay found?

523. What natural fertilizers are found in the State, and in what counties?

524. What does analyses show green sand to contain?

525. Give some account of the glass-making material of Tennessee.

CHAPTER XX.

State the subject of this chapter.

526. In what counties are the phosphates found?

527. What amount was mined in Tennessee in 1898? What amount since its discovery in 1893?

528. How many kinds of phosphates are found in Tennessee? Name them.

529. In what formation are the Mt. Pleasant and Hudson phosphates found?

530. To what bed does the Mt. Pleasant belong? Give the Nashville series of rock, and name the distance between the Mt. Pleasant and Hudson phosphates. What is the thickness of the series?

531. What may be traced in the Mt. Pleasant district as to the formation of phosphates?

532. What interrupt the beds of the Mt. Pleasant phosphate, and what are these interruptions called? Give the thickness of the phosphate beds at Mt. Pleasant.

533. What is the appearance of this phosphate rock, and what amount is mined from an acre?

534. Give the average analyses of the Mt. Pleasant phosphate. What is the estimated amount of phosphate rock in the Mt. Pleasant district?

535. What is said of the Mt. Pleasant phosphate in other counties?

536. In what counties is the College or Hudson phosphate found?

537. What is said of the Swan Creek or Devonian phosphate? How many varieties are there?

538. Where is the largest quantity of the brown variety found? What is the thickness of the seam? How is the seam containing the hard rock divided? What do the analyses of the hard rock show?

539. How is the Swan Creek or "Blue-Rock" rock regarded in

the making of fertilizers? What is the estimated quantity of the blue phosphate?

540. What is said of the phosphate balls of the Maury green shale?

541. What is said of the precipitated phosphates?

542. Give the history of the discovery of the phosphate rock in Tennessee.

543. For what are phosphates used, and how? What effect will this discovery have upon agriculture?

CHAPTER XXI.

Of what does this chapter treat?

544. What is soil? What is subsoil?

545. How may all soils be divided? What are soils in place? State what is meant by transported soils.

546. Into what two parts may the composition of soils be divided? What is meant by the organic part? What by the inorganic?

547. Name the principal ingredients of a soil.

548. How are hard rocks changed into soil?

549. How may the soils of Tennessee be classified? What is said of the granitic soil? Of the sandstone soil? Of the siliceous or flinty? Of the sandy soil? Of the calcareo-siliceous? Of the calcareous soils? Of the green sand soil? Of the shaly soils and of the alluvial soils?

550. Where are the granitic soils of Tennessee found, and to what crops are they adapted?

551. How many varieties of sandstone soils are there? Name them.

552. For what is the Chilhowee sandstone soil suited? Where is it found? For what special use is it fitted? How much siliceous matter does it contain?

553. What is said of the Knox sandstone soil?

554. What is said of the Clinch Mountain soil, and where does it occur?

555. What singular fact may be mentioned as to the differences of soil on certain mountains?

556. Describe the Dyestone soil.

557. What is said of the soil of the Cumberland Table-land? What are its defects?

558. What are the characteristics of the best soils of this divi-

sion? In what does the greatest agricultural value of this soil consist? To what crops is it best adapted? What does chemical analyses show?

559. Describe the siliceous or flinty soil.

560. What two varieties of this soil are found associated? Describe both.

561. What is said of the soil of the "barrens?"

562. Describe the sandy soils.

563. Is a soil necessarily poor because it is sandy? Describe some of the good qualities of the sandy soils. What soils of Tennessee are best for the growth of cotton?

564. Where is the calcareo-siliceous soil found? Give the substance of what is said about it. What crops grow on it?

565. What is said of calcareous soils?

566. In what do they surpass all other soils in the State? Where are they found, and how are they classified? How much of the surface of the State do they cover? What constituents do the tobacco soils of Robertson and Montgomery Counties show?

567. What is said of the green sand soil?

568. What of the shaly soil, and what are its characteristics?

569. Give a description of the alluvial soils of the State. How much area do they occupy? How do they differ in character, and why this difference?

570. What is said of the terraces on the streams? For what crops are these terraced lands adapted?

571. How do the various soils overlap and run into one another? Name some of the varieties of soil so formed.

572. Upon what does the productiveness of a soil depend?

573. What effect has standing water on field crops? What effect does great porosity in the soil have? What is the best condition of a soil for the purpose of production? How much heat will calcareous soils absorb? How much will clayey or argillaceous soils absorb? What effect does this capacity of different soils for the absorption of heat have upon the climate?

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